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PRELIMINARY AIRWORTHINESS EVALUATION OF THE UH-60A EQUIPPED WITH THE XM-139 VOLCANO MINE DISPENSING SYSTEM

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FINAL REPORT

Approved for public release; distribution unlimited.

AVIATION ENGINEERING FLIGHT ACTIVITY
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A Preliminary Airworthiness Evaluation of the UH-60A helicopter (S/N 84-23953) with the XM-139 VOLCANO system installed was conducted by the U.S. Army Aviation Engineering Flight Activity. The test was conducted at the Sikorsky Flight Test Facility at West Palm Beach, Florida (elevation 28 feet). Tests totaling 22.4 hours of productive flight time were conducted between 21 January and 27 February 1987. Tests were conducted to determine handling qualities and performance of the UH-60A in the VOLCANO system configuration at an average mission gross weight of 20,500 pounds and a longitudinal center of gravity at fuselage station 351.0 The handling qualities of the UH-60A with the VOLCANO system installed were similar to the normal utility UH-60A. Three shortcomings were noted in this configuration: (1) the increased frequency and magnitude of "tail shake" with the VOLCANO installed; (2) the position error for the ship's airspeed system was increased by approximately 2 knots at low speed (45 knots calibrated airspeed (KCAS)) and approximately 8 knots at higher speeds (120 KCAS) due to the installation of the VOLCANO mine dispensing system; and (3) Stability Augmentation-

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System (SAS) OFF dynamic response, not attributed to the VOLCANO installation, was aperiodic and divergent. The UH-60A helicopter with VOLCANO failed to meet two requirements of the Prime Item Development Specification ~~(PIDS)~~; however, these noncompliances were not significant. Recommendations were made to incorporate data into the applicable portion of the VOLCANO operator's manual and to conduct additional testing.

[illegible] Flight testing, Aerial mine dispersers, [illegible]

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INTRODUCTION

BACKGROUND

1. The U.S. Army is investigating the potential of the UH-60A Black Hawk helicopter for carrying the XM-139 VOLCANO mine dispensing system. The airborne dispensing system, designed to launch a mix of anti-tank and anti-personnel mines, was developed by the U.S. Army Aviation Research, Development and Engineering Center in conjunction with the Program Manager for Mines, Countermines and Demolition. The development effort was initiated in response to a requirement of the High Technology Light Division for a helicopter mine dispensing system. The prime development contractor for the XM-139 VOLCANO system is Honeywell, Inc. The U.S. Army Armament, Munitions, and Chemical Command has been tasked with system production and has in turn requested support from the U.S. Army Aviation Systems Command (AVSCOM) for qualification of the airborne system. On 14 November 1986, AVSCOM tasked the U.S. Army Aviation Engineering Flight Activity (AEFA) (ref 1, app A) to plan, conduct and report on a Preliminary Airworthiness Evaluation (PAE) of the UH-60A with the XM-139 VOLCANO mine dispensing system installed.

TEST OBJECTIVE

2. The objective of this evaluation was to conduct a limited handling qualities and performance evaluation of the UH-60A helicopter with the XM-139 VOLCANO system installed. Data will be used by AVSCOM to determine the airworthiness of the VOLCANO installation and the associated limitations to the UH-60A flight envelope.

DESCRIPTION

3. The UH-60A is a twin-engine, single main rotor configured helicopter with a fixed wheel-type landing gear. The main and tail rotors are both four-bladed with a capability of manual main rotor blade and tail pylon folding. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. A more detailed description of the UH-60A helicopter is contained in the operator's manual (ref 2). The test helicopter, UH-60A Black Hawk, U.S. Army S/N 84-23953, equipped with fixed provision mounting points, was configured with the VOLCANO mine dispensing system (photo 1). The VOLCANO system evaluated consisted of four launching racks loaded with 160 slug (inert) mine canisters, the aircraft mounting kit hardware, and fully operational rack jettison mechanisms. The Dispenser Control Unit was not installed for this evaluation. The VOLCANO system

Photo 1. UH-60A Test Aircraft S/N 84-23953 with XM-139 VOLCANO Mine Dispenser System Installed

was mounted on the sides of the aircraft fuselage outboard of the sliding doors. A more detailed description of the VOLCANO mine dispensing system is included in references 3 and 4, and in appendix B.

TEST SCOPE

4. The PAE was performed by AEFA personnel at the Sikorsky Flight Test Facility at West Palm Beach, Florida (elevation 28 feet). Tests totaling 22.4 hours of productive flight time were conducted between 31 January and 27 February 1987. The contractor provided all maintenance and logistical support of the test aircraft and test instrumentation and provided data reduction support. Tests were conducted to determine handling qualities and performance of the UH-60A in the VOLCANO system configuration at an average mission gross weight of 20,500 pounds and a longitudinal center of gravity at fuselage station 351.0. Results were compared to the requirements of MIL-H-8501A (ref 5, app A). Flight restrictions and operating limitations observed throughout the evaluation are contained in the operator's manual (ref 2) and the airworthiness release issued by AVSCOM (ref 6). Testing was conducted in accordance with the approved test plan (ref 7) at the conditions shown in tables 1 and 2.

TEST METHODOLOGY

5. The flight test data were recorded by hand from test instrumentation displayed in the cockpit, by on-board magnetic tape recording equipment and via telemetry to Sikorsky's Real-Time Acquisition and Processing of Inflight Data system. A detailed listing of test instrumentation is contained in appendix C. Flight test techniques and data reduction procedures are described in appendix D.

Table 1. Level Flight Performance Test Conditions[1]

Average Gross Weight (lb)	Average Thrust Coefficient (x10⁴)	Average Longitudinal Center of Gravity (FS)[2]	Average Density Altitude (ft)	Airspeed Range (KTAS)[3]	Configuration
17,720	79.66	350.4	7,930	49 to 160	Normal Utility
17,840	90.22	350.9	10,870	51 to 151	
17,820	100.40	350.9	13,290	53 to 133	
20,450	79.85	350.7	3,010	44 to 128	VOLCANO Installed
20,500	89.98	350.7	6,260	46 to 124	
20,650	99.96	[illegible]	9,330	49 to 111	

NOTE:

[1]Tests conducted with doors and windows closed, SAS ON, PRA centered and locked, and engine bleed air systems OFF. Main rotor speed of 258 referred rpm, approximate mid lateral cnter of gravity location.
[2]FS: Fuselage station.
[3]KTAS: Knots true airspeed.

Table 2. Handling Qualities Test Conditions[1]

Type of Test	Average Gross Weight (lb)	Average Longitudinal Center of Gravity (FS)[2]	Average Density Altitude (ft)	Trim Calibrated Airspeed (kt)	Remarks
Control Positions in trimmed forward flight[3,4]	17,790	350.7	7,930 to 13,290	42 to 143	Normal utility configuration (no VOLCANO)
	20,530	350.9	3,010 to 9,330	42 to 122	VOLCANO installed
Static Longitudinal Stability[3]	20,690	351.4	4990	81 and 118	Level flight
	20,680	351.3	5000	82	IRP[5] climbs and 1000 fpm[6] descents
Static Lateral-Directional Stability	20,6[illegible]	351.2	5200	82 and 119	Level flight
	20,680	351.3	4890	83	IRP climbs and 1000 fpm descents
Maneuvering Stability[3]	20,760	350.2	5680	40 and 102	SAS[7] and FPS[8] ON and SAS and FPS OFF. Left and right steady turns, symmetrical pull-ups and pushovers
Dynamic Stability[3]	20,500	350.6	5120	81 and 120	Level flight; SAS and FPS ON and SAS and FPS OFF
	20,560	350.1	4560	82	IRP climbs and 1000 fpm descents
Controllability in Hover	20,360	350.4	-160	0	Wheel height 50 feet
Low Speed Flight	20, 490	350.9	290	0 to 40 (KTAS)[9]	Azimuths: 0°, 90°, 180°, 270°, 315°. Wheel height 30 feet
Simulated Single-Engine Failures[3]	20,310	350.0	5140	82 to 117	Level flight
	20,170	349.6	5260	85	IRP climb

NOTES:

[1]Test conducted with VOLCANO installed and AFCS ON unless otherwise indicated, PBA centered and locked. Rotor speed of 258 rpm, and mid lateral center of gravity location.
[2]FS: Fuselage station.
[3]Test conducted in ball-centered flight.
[4]In conjunction with level flight performance, trim and FPS OFF.
[5]IRP: Intermediate rated power.
[6]fpm: Feet per minute
[7]SAS: Stability Augmentation System.
[8]FPS: Flight Path Stabilization.
[9]KTAS: knots true airspeed.

RESULTS AND DISCUSSION

GENERAL

6. A Preliminary Airworthiness Evaluation (PAE) of the performance and handling qualities of the UH-60A with the XM-139 VOLCANO mine dispensing system installed was conducted at the Sikorsky Aircraft Development Flight Test Center at West Palm Beach, Florida. The handling qualities of the UH-60A with the VOLCANO system installed were similar to the normal utility UH-60A. Three shortcomings were noted in this configuration: (1) the increased frequency and magnitude of "tail shake" with the VOLCANO installed; (2) the position error for the ship's airspeed system was increased by approximately 2 knots at low speed (45 knots calibrated airspeed (KCAS)) and approximately 8 knots at higher speeds (120 KCAS) due to the installation of the VOLCANO mine dispensing system; and (3) Stability Augmentation System (SAS) OFF dynamic response, not attributed to the VOLCANO installation, was aperiodic and divergent. The UH-60A helicopter with VOLCANO failed to meet two requirements of the Prime Item Development Specification (PIDS) (ref 8, app A), however, these noncompliances were not significant. Recommendations were made to incorporate data into the applicable portion of the VOLCANO operator's manual and to conduct additional testing.

LEVEL FLIGHT PERFORMANCE

7. Limited performance flight testing was conducted on the UH-60A helicopter to determine the performance differences between the UH-60A helicopter with the fixed provision fairings installed (normal utility) and the UH-60A configured with the VOLCANO system. Level flight performance tests were conducted at the conditions listed in table 1 to determine power required at various airspeeds. Each test was flown in ball-centered flight. Nondimensional level flight test results in the normal utility configuration are presented in figures 1 through 3, appendix E. Dimensional level flight test results are presented in figures 4 through 6. The VOLCANO configuration test results are presented in figures 7 through 9. With the VOLCANO installed on the UH-60A helicopter, change in equivalent flat plate area (ΔF_e) varied as a function of thrust coefficient (C_T) and airspeed from approximately 42 sq ft at a C_T of 0.008 to approximately 55 sq ft at a C_T of 0.010 as described in paragraph 10, appendix D. A pitch attitude difference, caused by the VOLCANO installation, was noted. At 40 KCAS, the normal utility aircraft and the UH-60A with VOLCANO exhibited the same pitch attitude. However, at 80 KCAS, the UH-60A with VOLCANO exhibited a 2° increased nose down pitch attitude when compared to the normal utility aircraft. This pitch attitude difference increased to 3° at

120 KCAS. The following CAUTION should be incorporated into the operator's manual.

CAUTION

> Prior to installation of the VOLCANO system, ensure that modified input modules (P/N 7035108001-046) have been installed in the aircraft. The increased nose-down pitch attitudes during level flight when the VOLCANO sytem is installed may result in oil foaming and inadequate lubrication without the required gearbox modification.

HANDLING QUALITIES

General

8. A limited handling qualities evaluation of the UH-60A configured with the VOLCANO mine dispensing system was conducted to determine any changes caused by the VOLCANO installation. Handling qualities of the UH-60A in the test configuration were qualitatively evaluated and found to be similar to the normal utility configured UH-60A. During a 40 knots indicated airspeed (KIAS) collective-fixed turn at 45 degrees angle-of-bank, the airspeed indication would abruptly decrease to zero. Airspeed could not be increased by application of forward cyclic in the turn. This condition of zero airspeed turn, which was not VOLCANO related, was perceived by the pilot as similar to a fixed-wing aircraft in a spin. Also not caused by the VOLCANO installation, the SAS OFF dynamic stability was aperiodic and divergent. With the VOLCANO installed, the aircraft exhibited an increased frequency and magnitude of "tail shake".

Control Positions in Trimmed Forward Flight

9. Control positions in trimmed, ball-centered, forward flight were obtained in conjunction with level flight performance testing at the conditions in table 2. Figures 10 through 15, appendix E, present the results of these tests. The variation of longitudinal control postion with airspeed during trimmed level flight generally required increasing forward cyclic control with increasing airspeed. The control positions in trimmed forward flight are similar to the normal UH-60A and are satisfactory.

Static Longitudinal Stability

10. The static longitudinal stability characteristics were evaluated at the conditions presented in table 2. The helicopter was stabilized in ball-centered flight at the desired trim airspeed and flight condition. The collective control was held fixed while airspeed was varied incrementally approximately ±20 knots about trim. Test results are shown in figures 16 through 18. The static longitudinal stability, as indicated by the variation of longitudinal cyclic control position with airspeed, was positive (0.025 in/kt) (forward longitudinal cyclic control position to maintain increased airspeed) at 81 KCAS, but neutral at maximum airspeed in level flight at intermediate rated power (IRP) V_H (118 KCAS). Control force cues of longitudinal cyclic control displacement about trim were weak, but sufficient for airspeed control within ± 2 knots during normal mission maneuvering. The static longitudinal stability characteristics were essentially the same during climbs, descents, and level flight and were similar to the normal utility UH-60A. The static longitudinal stability characteristics are satisfactory, but did not meet the requirements of MIL-H-8501A in that the static longitudinal stability was neutral at V_H.

Static Lateral-Directional Stability

11. The static lateral-directional stability characteristics were evaluated at the conditions presented in table 2. The helicopter was stabilized in ball-centered flight at the desired trim airspeed and flight condition. The collective control was held fixed and sideslip angle was varied incrementally (left and right) while maintaining constant airspeed and ground track. Test results are shown in figures 19 through 21. Apparent static directional stability, as indicated by the variation of directional control position with sideslip angle, was positive (left pedal for right sideslip angles) and essentially linear. Dihedral effect, as indicated by the variation of lateral cyclic control position with sideslip angle, was positive (right cyclic control for right sideslip angles) and essentially linear. The sideforce characteristics, as indicated by the variation of bank angle with sideslip, were positive (right bank angle with right sideslip). The UH-60A exhibited pitch with sideslip coupling (variation of longitudinal control position with sideslip) and although it was noticeable to the pilots it was not considered objectionable. During the 83 KCAS climb, the left pedal stop was contacted at approximately 21 degrees right sideslip angle, 2 degrees prior to reaching the limit sideslip angle of 23 degrees right. This was not considered to be a significant finding. The static lateral-directional stability characteristics were essentially

the same during climbs, descents, and level flight. During cruise flight, the aircraft trim condition was maintained within ±2 degrees of heading and bank angle, and ±1/2 ball width from trim with little pilot compensation (Handling Qualities Rating Scale (HQRS 2)). The static lateral-directional stability characteristics in all flight conditions are satisfactory and met the requirements of MIL-H-8501A.

Maneuvering Stability

12. Maneuvering stability was evaluated at the conditions presented in table 2 in left and right collective-fixed, steady-state turns, symmetrical pull-ups and pushovers. The steady-state turn tests were accomplished by initially stabilizing the helicopter in ball-centered level flight at the trim airspeed and then incrementally increasing the normal acceleration (g) by increasing the bank angle in left and right turns. Constant collective control position was maintained during the maneuvers and the pilot attempted to maintain a constant airspeed. Symmetrical pull-ups and pushovers were conducted by alternately climbing and diving the helicopter to achieve varying g while the aircraft was passing through the trim altitude at the desired airspeed. Test results are presented in figures 22 through 25.

13. The stick-fixed maneuvering stability, as indicated by the variation of longitudinal cyclic control position with g, was positive (increasing aft cyclic control with increasing g). There were no significant differences in the handling qualities characteristics between right and left turns. The variation in longitudinal control positions with g was essentially linear and the lateral cyclic control position remained essentially constant at all bank angles. The longitudinal control force cues were adequate at bank angles greater than 15 degrees. The maneuvering stability characteristics were similar to the normal utility UH-60A and are satisfactory.

14. Maneuvering stability was evaluated at 40 KIAS in angles of bank from 15 to 45 degrees. The aircraft was stabilized at 40 KIAS and bank angle was increased in 15 degree increments. If the airspeed was allowed to decrease below 40 KIAS while stabilizing at 45 degrees angle of bank airspeed indication would abruptly decrease to zero. Increasing forward longitudinal cyclic caused the pitch attitude to decrease (nose further down), but did not increase the airspeed. This condition was perceived by the pilot as being similar to a fixed-wing aircraft in a spin. The aircraft was easily recovered by rolling out of the turn using lateral cyclic and opposite pedal. As the airspeed increased, aircraft recovery was completed by the application of aft cyclic.

A similar result occurred when this test was repeated without the VOLCANO installed. This is characteristic of the helicopter and not VOLCANO related, but has not been previously documented. The following note should be incorporated into chapter 5 of the operator's manual (ref 2, app A).

NOTE

> While flying at 40 KIAS or below, maneuvers should be limited to less than 45° angle of bank to prevent inadvertent entry into a spin type maneuver, characterized by zero airspeed indication, in which forward cyclic results in an increased nose down pitch attitude without the expected and corresponding airspeed increase. Upon inadvertent entry into this flight condition, recovery should be effected by rolling out of the turn first, and applying aft cyclic to return to level flight.

Dynamic Stability (Gust Response)

15. The dynamic stability characteristics were evaluated at the conditions presented in table 2. The gust response characteristics were evaluated qualitatively in calm to light turbulence conditions as defined in the DoD Flight Information Handbook (ref 9). The helicopter response was evaluated using one-inch 0.5 second control pulses in level flight, climbs and descents at 80 KCAS, SAS ON and SAS OFF. Additional control pulses were evaluated in level flight at V_H (120 KCAS), SAS ON and SAS OFF. Representative time history data (80 KCAS) are presented in figures 26 through 39, appendix E. SAS ON dynamic response was deadbeat. SAS OFF dynamic response was aperiodic and divergent. Control pulses in other axes rapidly coupled into the longitudinal axis. During descents, the SAS OFF response rates were noticeably higher than during the other test conditions. Pilot workload during SAS OFF level flight requires continuous, small ($\pm 1/4$ inch) longitudinal control inputs to maintain airspeed ± 5 KIAS (HQRS 3). Steady heading sideslip releases in level flight, climbs and descents were also evaluated. Pedal releases (SAS ON) at a 10 degree sideslip angle (left and right) resulted in a rapid return to within 1/2 ball-width of trim with no more than one heading overshoot of approximately 2 degrees. Long-term longitudinal dynamic stability was evaluated by observing the aircraft response after displacing the aircraft from trim airspeed approximately 10 to 15 knots and smoothly returning the longitudinal control to the trim position. With SAS ON, the aircraft immediately began to return to trim. The aircraft was flown "hands off" for extended time periods (greater than 1 minute) in

light turbulence with only small transient airspeed and altitude fluctuations noted. The SAS ON dynamic stability characteristics are satisfactory and met the specification requirements. The aperiodic divergent SAS OFF dynamic stability is a shortcoming. This is characteristic of the normal utility UH-60A and is not attributed to the VOLCANO installation.

Controllability in Hover

16. Controllability tests were conducted during hover to evaluate the control power, response, and sensitivity characteristics. Controllability was measured in terms of aircraft attitude displacement (control power), maximum angular velocities (control response), and maximum angular accelerations (control sensitivity) about an aircraft axis following a control step input of a measured size. Following the input, all controls were held fixed until a maximum rate was established or until recovery was necessary. The magnitude of inputs was varied by using an adjustable rigid control fixture on the cyclic control and the directional pedals. Real time telemetry monitoring was utilized to confirm the desired input size and shape. Controllability tests were conducted at the conditions presented in table 2.

17. Longitudinal controllability characteristics and representative time histories are presented in figures 40 through 42, appendix E. Longitudinal control power (pitch attitude change within one second following a one inch input) and longitudinal control response (maximum pitch rate per inch of control input) were similar in both the forward and aft directions. The rates and accelerations were linear with respect to control input magnitude. The longitudinal control response was predictable with no tendency to overcontrol. The longitudinal controllability characteristics are satisfactory and met the requirements of MIL-H-8501A.

18. Lateral controllability characteristics and representative time histories are presented in figures 43 through 45. The lateral control power, response, and sensitivity did not change with the direction of input. The lateral controllability characteristics are satisfactory and met the requirements of MIL-H-8501A.

19. Directional controllability characteristics and representative time histories are presented in figures 46 through 48. The control response was predictable with no tendency to overcontrol. The rates and acceleration were linear with respect to control input magnitude. The directional controllability characteristics are satisfactory and met the requirements of MIL-H-8501A.

Low Speed Flight Characteristics

20. The low speed flight characteristics were evaluated at the conditions presented in table 2. Tests were conducted at true airspeeds up to 40 knots in forward and rearward (0° and 180° relative azimuths) and sideward (090°, 270°, and 315° relative azimuths) flight at a wheel height of 30 feet (as measured by the radar altimeter). Surface winds were 5 knots or less and a ground pace vehicle was used as a speed reference. The low speed flight test data are presented in figures 49 through 51.

21. The flight control trends in rearward flight (fig. 49) were unconventional in that a nominal longitudinal cyclic position of approximately 6.4 in. was maintained between 0 and 15 knots true airspeed (KTAS). Qualitatively, longitudinal cyclic position and force cues were minimal at airspeeds less than 20 KTAS. Additionally, larger control inputs were required above 20 KTAS, however, overall control input frequency was noticeably less. The stabilator remained programmed in the full trailing edge down (40°) position throughout this portion of the evaluation and adequate control margins remained during both forward and rearward flight. The low speed flight characteristics during forward and rearward flight are similar to the normal utility UH-60A and are satisfactory.

22. The flight control trends during left and right sideward flight (fig. 50) were conventional. During left sideward flight, the lateral cyclic position cues were noticeably weaker than during right sideward flight. Stabilator programming began to occur at approximately 15 KTAS during left sideward flight, while the stabilator remained programmed in the full trailing edge down (40°) position during right sideward flight. During left sideward flight, the frequency of control inputs was very high (almost continuous) in all control axes. Adequate control margins remained throughout this evaluation. Aircraft vibrations were noticeably higher during left sideward flight (Vibration Rating Scale (VRS 6)). In addition to the typical airframe shudder, an intermittent lateral "tail shake" (as discussed in para 25) was noted. The low speed flight characteristics during left and right sideward flight are similar to the normal utility UH-60A and are satisfactory.

23. The flight control trends during sideward flight at a relative wind azimuth of 315 degrees (fig. 51) were non-linear, but were not objectionable. The non-linearities occurred as the stabilator began to program inconsistently above approximately 15 KTAS. There were adequate control margins throughout the evaluation. The "tail shake" discussed in paragraph 25 occurred at a higher frequency and greater magnitude than during the other wind azimuths

evaluated. The low speed characteristics during sideward flight at a relative wind azimuth of 315° were similar to a normal utility UH-60A and are satisfactory.

Simulated Single-Engine Failure

24. Simulated single engine failures were evaluated at the conditions presented in table 2. Representative time histories of the simulated engine failures during level flight and in an IRP climb are presented in figure 52. The engine failures were simulated by pulling one engine power control lever from the flight position to the idle position and delaying pilot reaction for a minimum of 2 seconds or until the low rotor speed warning sounded. There were no differences (handling qualities or failure cues) noted between a "failed" left engine or a "failed" right engine. The simulated engine failures were detected by an audible warning tone, an ENG OUT master caution light, a difference in cockpit engine parameters, and a noticeable 2 to 4 deg left yaw. Other than the yaw excursion, no unusual attitude changes or control forces were observed during the simulated engine failures and the subsequent transition to single-engine flight. At high collective pitch settings, main rotor speed decreased rapidly, but normal operating rotor speed was easily restored by reducing the collective pitch control. The simulated single-engine failure characteristics are satisfactory.

VIBRATION

25. Intermittent, variable intensity lateral accelerations were noted in the cockpit with the VOLCANO installed. Sikorsky flight test personnel commonly referred to this as "tail shake". Tail shake appears to be associated with disturbed airflow across the stabilator surface which transmits a lateral "kick" into the cockpit. The frequency and magnitude of the lateral kicks increased noticeably during descents, left sideslip maneuvers, left turns and at V_H. Observations from the chase aircraft indicate that the entire stabilator intermittently rocks laterally a noticeable amount. Stabilator tip vibration data indicates occasional spike loads of 10 g's with nominal alternating loads of approximately 4 g's. Stabilator mount bushing wear was monitored and an increase in mount bushing wear was noted. Upon further investigation, tail shake was apparent in a normal utility UH-60A under similar flight conditions, but the frequency and magnitude were noticeably less. The excessive magnitude of the tail shake with the VOLCANO installed is a shortcoming. A detailed maintenance evaluation should be conducted to determine potential increased maintenance and supply system impacts pursuant to VOLCANO operations.

AIRSPEED CALIBRATION

26. Airspeed calibration tests were conducted to determine the position error of the UH-60A's airspeed system in both the clean (normal utility) configuration and with the VOLCANO system installed. The aircraft's pitot-static system was calibrated during level flight over a measured ground speed course and by use of a calibrated trailing bomb (finned pitot-static system). The aircraft was flown up to 122 KIAS using the trailing bomb method and up to 156 KIAS using the ground speed course. Data are presented in figures 55 and 56. The position error increased approximately 2 knots at lower speeds (45 KCAS) and approximately 8 knots at higher speeds (120 KCAS) due to the installation of the VOLCANO mine dispensing system. This large position error associated with the VOLCANO installation will result in a discrepancy between the desired mine dispensing airspeed and the actual dispensing airspeed, affecting the mine field density, and is a shortcoming. The position error data presented in figure 56, should be incorporated into the applicable VOLCANO mine dispensing system operator's manual.

CONCLUSIONS

GENERAL

27. Based on this evaluation, the following conclusions were reached about the UH-60A Black Hawk with the XM-139 VOLCANO system installed.

a. With the VOLCANO system installed on the UH-60A helicopter, change in flat plate area (ΔF_e) varied as a function of coefficient of thrust (C_T) and airspeed from approximately 42 sq ft at a C_T of 0.008 to approximately 55 sq ft at a C_T of 0.010 (para 7).

b. An increased nose down pitch attitude difference, attributable to the VOLCANO installation, was noted (para 7).

c. Handling qualities of the UH-60A helicopter were not significantly changed by the installation of the XM-139 VOLCANO system (para 8).

SHORTCOMINGS

28. The following shortcomings were identified and are listed in order of importance.

a. The excessive magnitude of the tail shake with the VOLCANO installed (para 25).

b. The large airspeed system position error associated with the VOLCANO installation (para 26).

c. The aperiodic dynamic instability with the SAS OFF at 80 KCAS with and without the VOLCANO installed (para 15).

SPECIFICATION COMPLIANCE

29. The UH-60A helicopter with VOLCANO failed to meet the following requirements of the PIDS (ref 8, app A).

a. Paragraph 10.3.3.1.3 - The static longitudinal stability was neutral at V_H (para 10).

b. Paragraph 10.3.3.2.1a - The SAS OFF dynamic stability, not attributed to the VOLCANO installation, was aperiodic and divergent (para 15).

RECOMMENDATIONS

30. The following recommendations are made.

a. The following NOTE should be incorporated into chapter 5 of the operator's manual (para 14).

NOTE

While flying at 40 KIAS or below, maneuvers should be limited to less than 45° angle of bank to prevent inadvertent entry into a spin type maneuver, characterized by zero airspeed indication, in which forward cyclic results in an increased nose down pitch attitude without the expected and corresponding airspeed increase. Upon inadvertent entry into this flight condition, recovery should be effected by rolling out of the turn first and applying aft cyclic to return to to level flight.

b. The following CAUTION should be incorporated into chapter 5 of the operator's manual (para 7).

CAUTION

Prior to installation of the VOLCANO system, ensure that modified input modules (P/N 70351080001-046) have been installed in the aircraft. The increased nose-down pitch attitudes during level flight when the VOLCANO sytem is installed may result in oil foaming and inadequate lubrication without the required gearbox modification.

c. A detailed maintenance evaluation should be conducted to determine potential increased maintenance and supply system impacts pursuant to VOLCANO operations (para 25).

d. The position error data presented in figure 56, appendix F should be incorporated into the applicable VOLCANO mine dispensing system operator's manual (para 26).

APPENDIX A. REFERENCES

1. Letter, AVSCOM, AMSAV-8, 14 November 1986, subject: Preliminary Airworthiness Evaluation (PAE) of the UH-60A/VOLCANO.

2. Technical Manual, TM 55-1520-237-10, *Operator's Manual, UH-60A Helicopter*, 21 May 1979 with change 40 dated 22 December 1986.

3. Draft Equipment Publication, DEP 9-1095-208-10, *Operator's Manual for XM-139 Mine Dispenser*, 12 November 1986.

4. Draft Equipment Publication, DEP 9-1095-208-23 & P (Manuscript), Technical Manual for the XM-139 Mine Dispenser, 18 November 1986.

5. Military Specification, MIL-H-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirements for*, with amendment 1, 3 April 1962.

6. Letter, AVSCOM, AMSAV-E, 30 January 1987, subject: Airworthiness Release for the Conduct of a Preliminary Airworthiness Evaluation of a UH-60A Configured with the XM-139 VOLCANO System.

7. Test Plan, USAAEFA Project No. 86-10, *Preliminary Airworthiness Evaluation of the UH-60A Equipped with the XM-139 VOLCANO Mine Dispensing System*, December 1986.

8. Prime Item Development Specification (PIDS), Sikorsky Aircraft, "DARCOM-CP-2222-3 1000E Part I, 13 April 1981.

9. DoD Flight Information Publication, *Flight Information Handbook*, Defense Mapping Agency Aerospace Center, 18 December 1986.

10. Engineering Design Handbook, Army Material Command, AMC Pamphlet 706-204, *Helicopter Performance Testing*, 1 August 1974.

11. Flight Test Manual, Naval Air Test Center FTM No. 101, *Stability and Control*, 10 June 1968.

APPENDIX B. DESCRIPTION

GENERAL

1. The UH-60A (Black Hawk) is a twin turbine engine, single main rotor helicopter with nonretractable wheel-type landing gear. A movable horizontal stabilator is located on the lower portion of the tail rotor pylon. The main and tail rotor are both four-bladed with a capability of manual main rotor blade and tail pylon folding. The cross-beam tail rotor with composite blades is attached to the right side of the pylon. The tail rotor shaft is canted 20° upward from the horizontal. Primary mission gross weight is 16,260 pounds and maximum alternate gross weight is 20,250 pounds. The proposed maximum gross weight is 22,000 pounds and the VOLCANO configured helicopter design gross weight is 20,572 pounds. The UH-60A is powered by two General Electric T700-GE-700 turboshaft engines having an installed thermodynamic rating (30 minute) of 1553 shaft horsepower (shp) (power turbine speed of 20,900 revolutions per minute) each at sea level, standard-day static conditions. Installed dual-engine power is transmission limited to 2828 shp. The aircraft also has an automatic flight control system and a command instrument system. The test helicopter, UH-60A U.S. Army S/N 84-23953, was manufactured by Sikorsky Aircraft Division of United Technologies Corporation and is a production Black Hawk equipped with fixed provision mounting points. These points provide the mounting for the VOLCANO system hardware. The main differences between the test aircraft and a normal utility UH-60A are the addition of and an external nose-mounted airspeed boom and special test instrumentation (app C), and the mounting of the VOLCANO system (photos 1 through 4, app F). A more complete description of the UH-60A helicopter can be found in reference 2, appendix A.

XM-139 VOLCANO MINE DISPENSER

2. The XM-139 VOLCANO weapons system with related equipment is produced by Honeywell, Inc. The VOLCANO is an automated, scatterable mine delivery system capable of launching mines from host ground and air vehicles (5 ton dump and cargo trucks and the UH-60A helicopter). The mine dispenser system is modular and consists of four major components: (1) mounting hardware kits, (2) four launcher racks, (3) 160 mine canisters, and (4) a Dispenser Control Unit (DCU). Dimensions and weights of these components are summarized in table 1 and aircraft mounting locations are shown in figure 1.

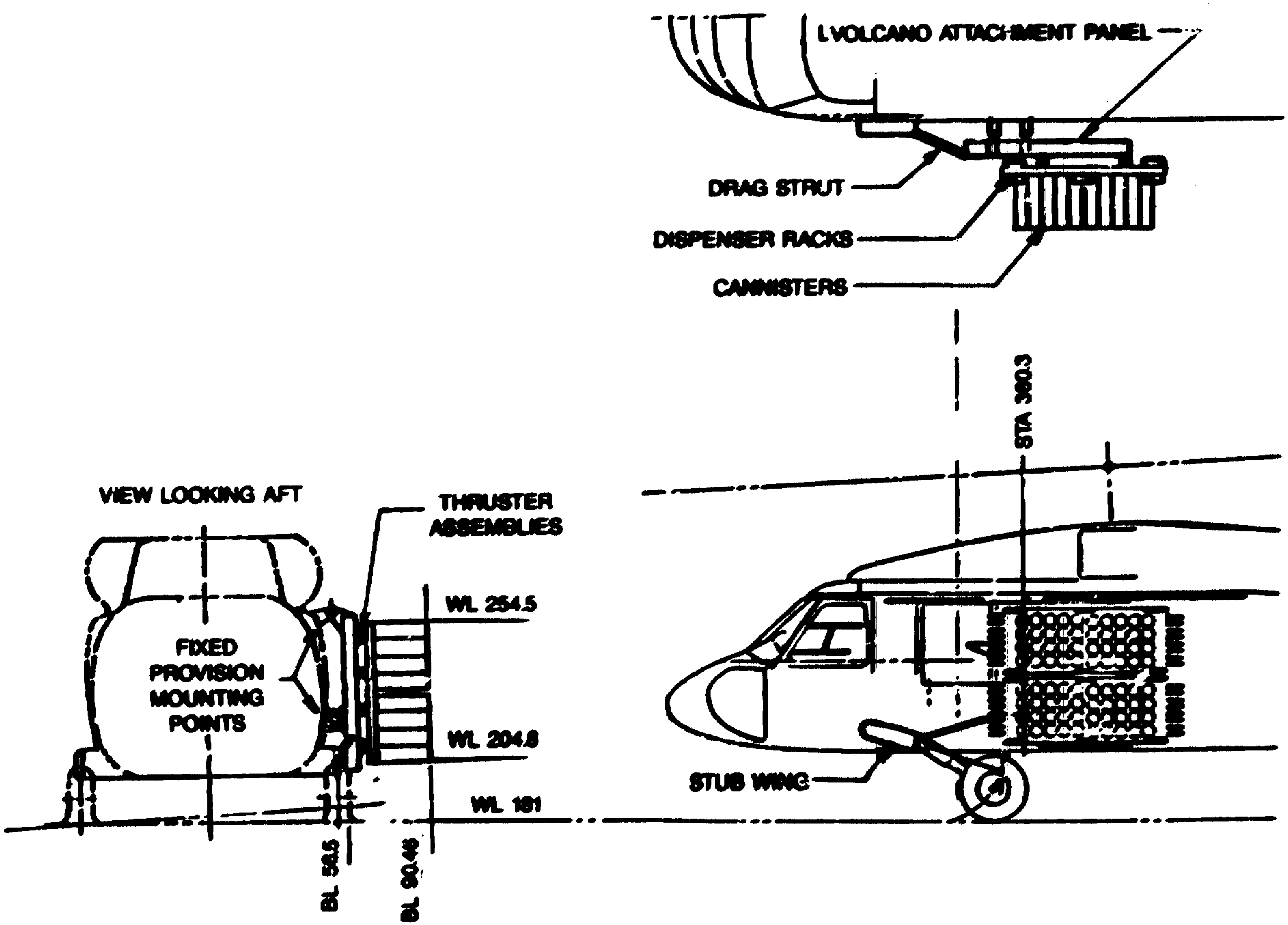


Figure 1. XM-139 VOLCANO Mine Dispenser System, UH-60A Black Hawk

Table 1. XM-139 Component Dimensions

	Dimensions (in.)			Weight (lb)
Component	Height	Length	Width	
UH-60A Side Panel (each)	58.5	57.25	6.25	238
Launcher Rack (each)	25.0	79.0	9.0	225
XM-88 Canisters (each)		24.0	5.0 (dia)	32
DCU	19	21	21	70

The mounting hardware (photos 5 through 7, app F) is the only application-unique system element and allows mounting to the Black Hawk fixed provision mounting points (photos 8 and 9) without any aircraft modifications. This hardware accepts up to four launcher racks (two per side) (photos 10 and 11), with each rack holding up to 40 individual XM-87 Mine Canisters (photos 12 and 13). Each canister contains a stack of five BLU-91/B anti-tank and one BLU-92/B anti-personnel GATOR mines giving the system a total delivery capability of 960 mines. A web assembly is interlaced between the mines providing dispersion and mine arming during firing. Inert XM-88 mine canisters were used for this test. They are identical to the XM-87 canisters except for color and markings, but contain no transmitter coils and six dummy mines. A frontal and side view of the completed installation are shown in photos 14 and 15, respectively. The XM-139 DCU mounted in the cargo compartment, is programmed by the operator with the selected dispensing speed and mine self-destruct time. It is designed to control firing of one to four racks in a prescribed sequence on alternating sides of the aircraft. This DCU was not installed on the aircraft. The interface control panel (photo 16), mounted on the center instrument console, and the go-around switch, located on both pilot and copilot cyclic controls, control the arming, firing and jettison of the launcher racks. The interface control panel allows the pilot to conduct a continuity test of the jettison system. The test aircraft was equipped with the jettison, but not the firing, capability. A more complete description of the system can be found in references 3 and 4, appendix A.

MODIFICATIONS

3. Several modifications were made to the test aircraft to accomodate ballast and instrumentation, or for safety purposes. These modifications were not part of the VOLCANO modifications or a normal utility UH-60A. Four mounting provisions were used to

accomodate ballast. These are shown in photos 17 through 19, appendix F. An instrumentation package was installed in the cargo compartment and can be seen in photos 20 and 21. Sikorsky drag estimates for the external items (photos 22 through 25) totalled 3.04 square feet of equivalent flat plate area. Each item is listed below:

<u>Item</u>

Standard size tail rotor slip ring
Medium size main rotor slip ring with cover
Nose boom
Tail-mounted TM antennas
Belly-mounted TM antenna
Main rotor instrumentation
Ambient air temperature sensor
Emergency crew door handles

APPENDIX C. INSTRUMENTATION

GENERAL

1. The test instrumentation was installed, calibrated and maintained by Sikorsky Aircraft personnel. A test boom, with a swiveling pitot-static tube and angle-of-attack and sideslip vanes, was installed at the nose of the aircraft. Three telemetry antennae were installed. Two were mounted to the top left side of the tail boom and one was mounted on the belly of the aircraft just forward of the tail boom. Slip ring assemblies were installed on the main and tail rotor shafts. All other instrumentation was installed inside the test aircraft. Data were obtained from calibrated instrumentation and displayed or recorded as indicated below.

Pilot Panel

Airspeed (boom)
Altitude (boom)
Rate of climb (boom)
Rotor speed (sensitive-percent)
Engine torque* **
Turbine gas temperature* **
Power turbine speed (Np)* **
Gas producer speed (Ng)* **
Control positions
  Longitudinal
  Lateral
  Directional
  Collective
Horizontal stabilator position
Angle of sideslip
Copilot Panel
Airspeed*
Altitude*
Rotor speed*
Engine torque* **
Fuel remaining* **
Total air temperature
Instrumentation controls
Run number
Event switch

2. Data parameters recorded on board the aircraft and available for telemetry include the following:

*Ship's system
**Both engines

Digital (PCM) Data Parameters

Airspeed (boom)
Altitude (boom)
Airspeed (ship's)
Altitude (ship's)
Radar altimeter (low range)
Total air temperature
Rotor speed
Gas generator speed **
Power turbine speed **
Engine fuel flow **
Engine fuel temperature **
Engine output shaft torque **
Turbine gas temperature **
Longitudinal acceleration at the cg
Lateral acceleration at the cg
Normal load factor at the cg
Stabilator position
Control positions
    Longitudinal
    Lateral
    Directional
    Collective
Attitude
    Pitch
    Roll
    Heading
Angular Acceleration
    Pitch
    Roll
    Yaw
SAS output position
    Longitudinal
    Lateral
    Directional
Main rotor shaft torque
Tail rotor shaft torque
Tail rotor impressed pitch (blade angle at 0.75 blade span)
Angle of sideslip
Angle of attack
Time of day
Run number
Pilot event switch

**Both engines

Analog (FM) Vibration Parameters

Vertical pilot seat
Lateral pilot seat
Longitudinal pilot seat
Vertical copilot seat
Lateral copilot seat
Lateral pilot floor
Vertical copilot floor
Vertical pilot instrument panel
Vertical copilot instrument panel
Center of gravity vertical
Center of gravity lateral
Center of gravity longitudinal
No. 1 engine exhaust frame vertical
No. 2 engine exhaust frame horizontal
No. 1 engine front frame longitudinal
No. 2 engine front frame longitudinal
Vertical side panel left forward lower
Vertical side panel left forward upper
Vertical side panel right forward upper
Vertical side panel left aft upper
Vertical side panel right aft upper
Lateral side panel left aft lower
Lateral side panel right aft lower
Lateral side panel left forward upper
Lateral side panel right forward upper
Lateral side panel left aft upper
Lateral side panel right aft upper
Lateral side panel right forward lower
Longitudinal side panel left aft upper
Longitudinal side panel right aft upper

TEST BOOM AIRSPEED SYSTEM

3. The test boom airspeed system mounted at the nose of the test aircraft provided measurements of airspeed and altitude. Sensors for angles of attack and sideslip were also mounted on the test boom (photo 22, app F). The tip of the swiveling pitot-static tube was 79.6 inches forward of the nose of the aircraft (fuselage station 97), 25.7 inches to the right of the aircraft reference buttline and 7 inches below the forward avionics bay floor, waterline 208.

FIGURE 1
BOOM AIRSPEED CALIBRATION
UH-60A USA S/N 84-23953

SYM	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
○	15270	350.6	0.2	3350	13.5	TRAILING BOMB
△	18600	350.6	0.2	6200	17.5	TRAILING BOMB
□	17500	350.0	0.2	-10	16.0	GRND SPD CRSE

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM

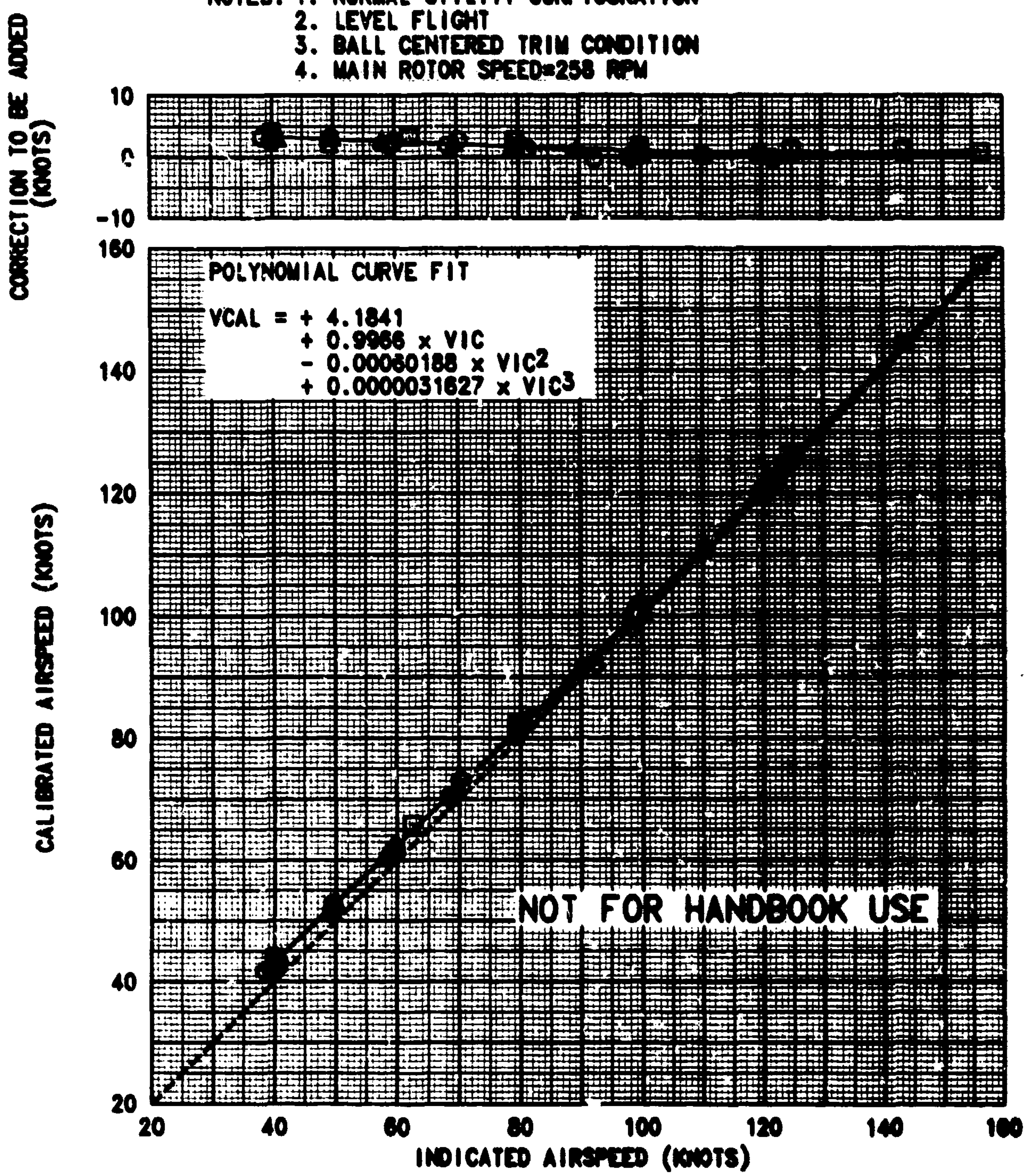


FIGURE 2

BOOM AIRSPEED CALIBRATION

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
20570	350.8	0.2	5200	6.5	TRAILING BOMB

NOTES:1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM

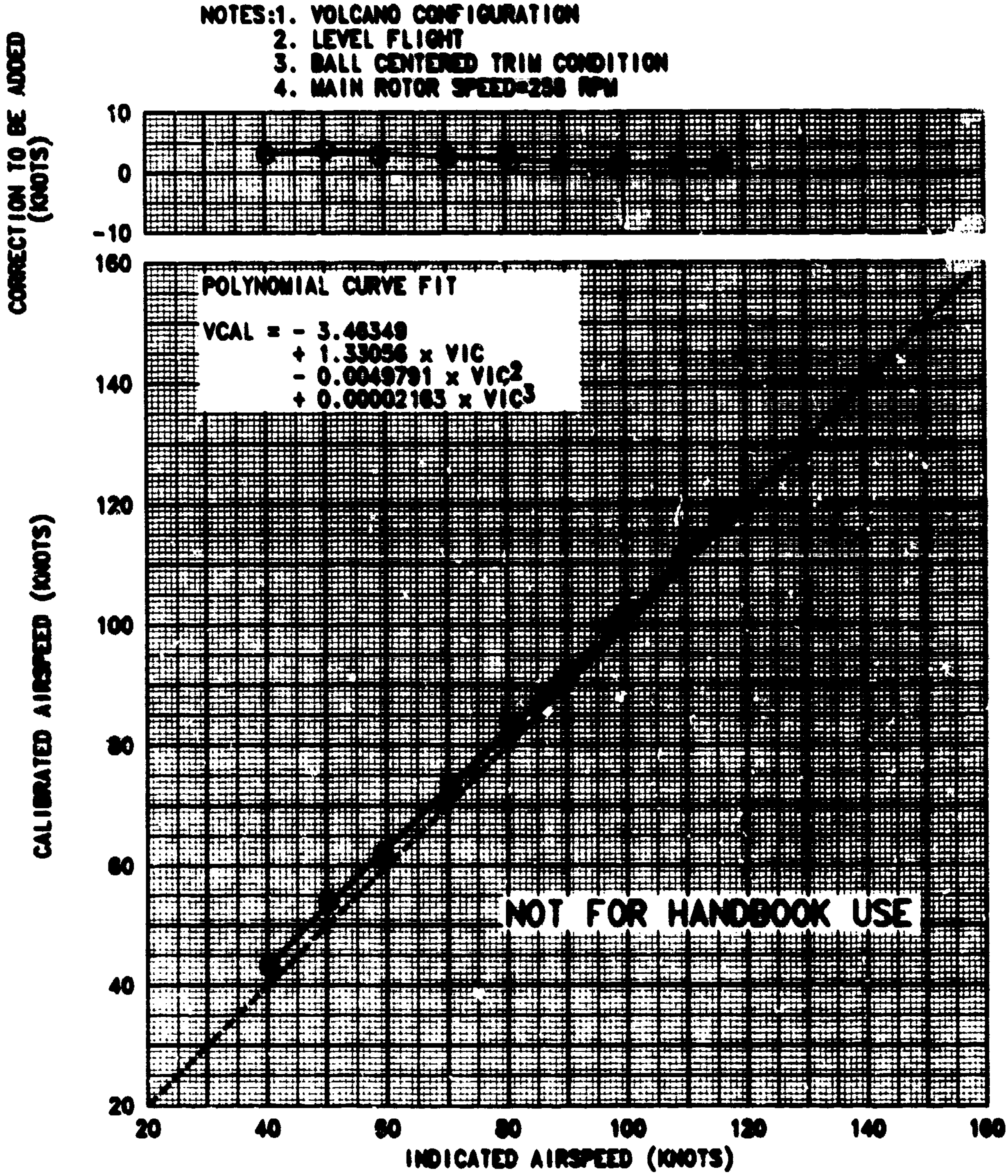


FIGURE 3

ENGINE TORQUEMETER CALIBRATION

UH-60A USA S/N 84-23953

T700-GE-700 S/N 306625

NOTES:
1. NUMBER ONE ENGINE
2. POWER TURBINE SPEED = 20,900 RPM
3. DATA OBTAINED FROM G E ENGINE PRODUCTION RATING SHEET

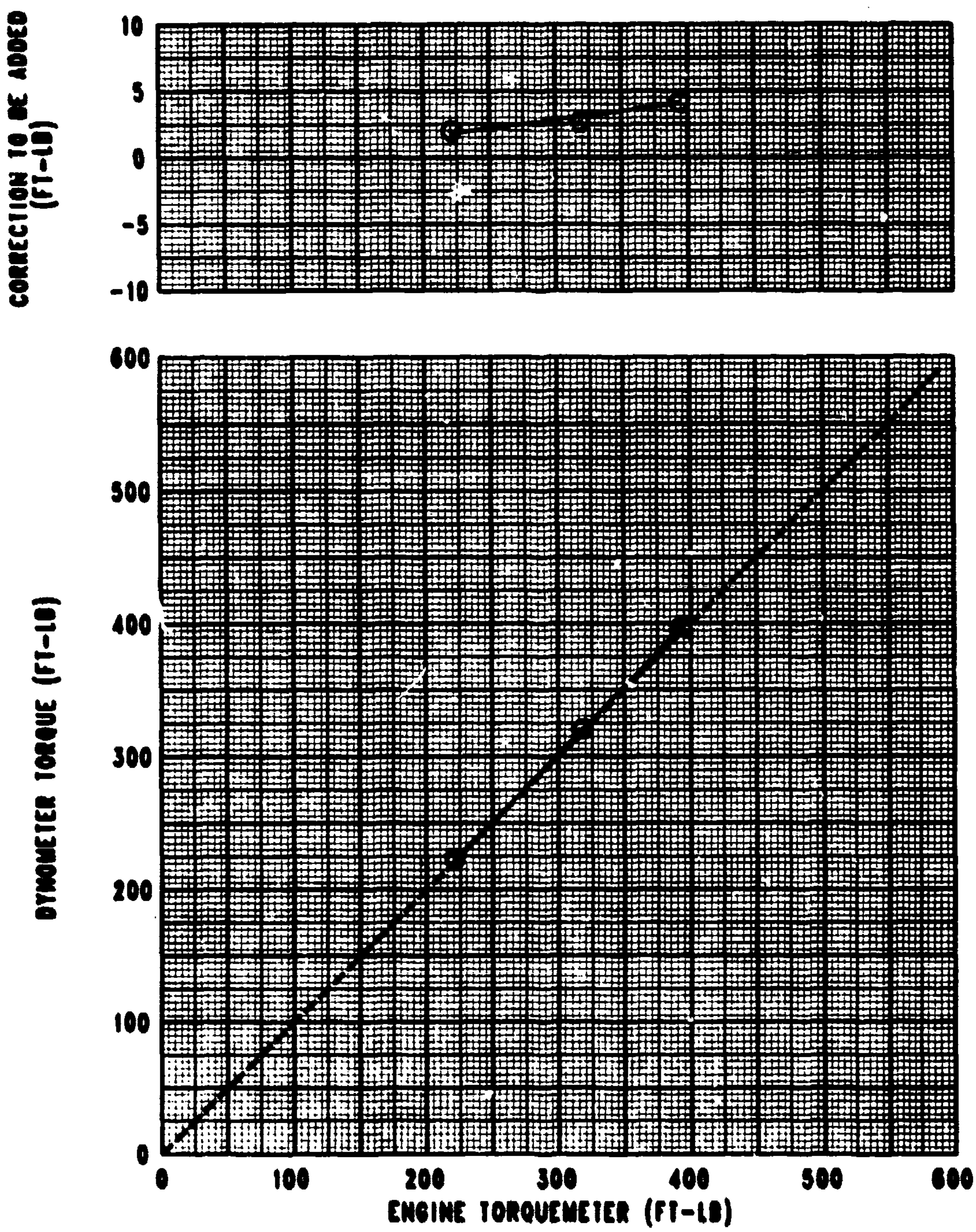
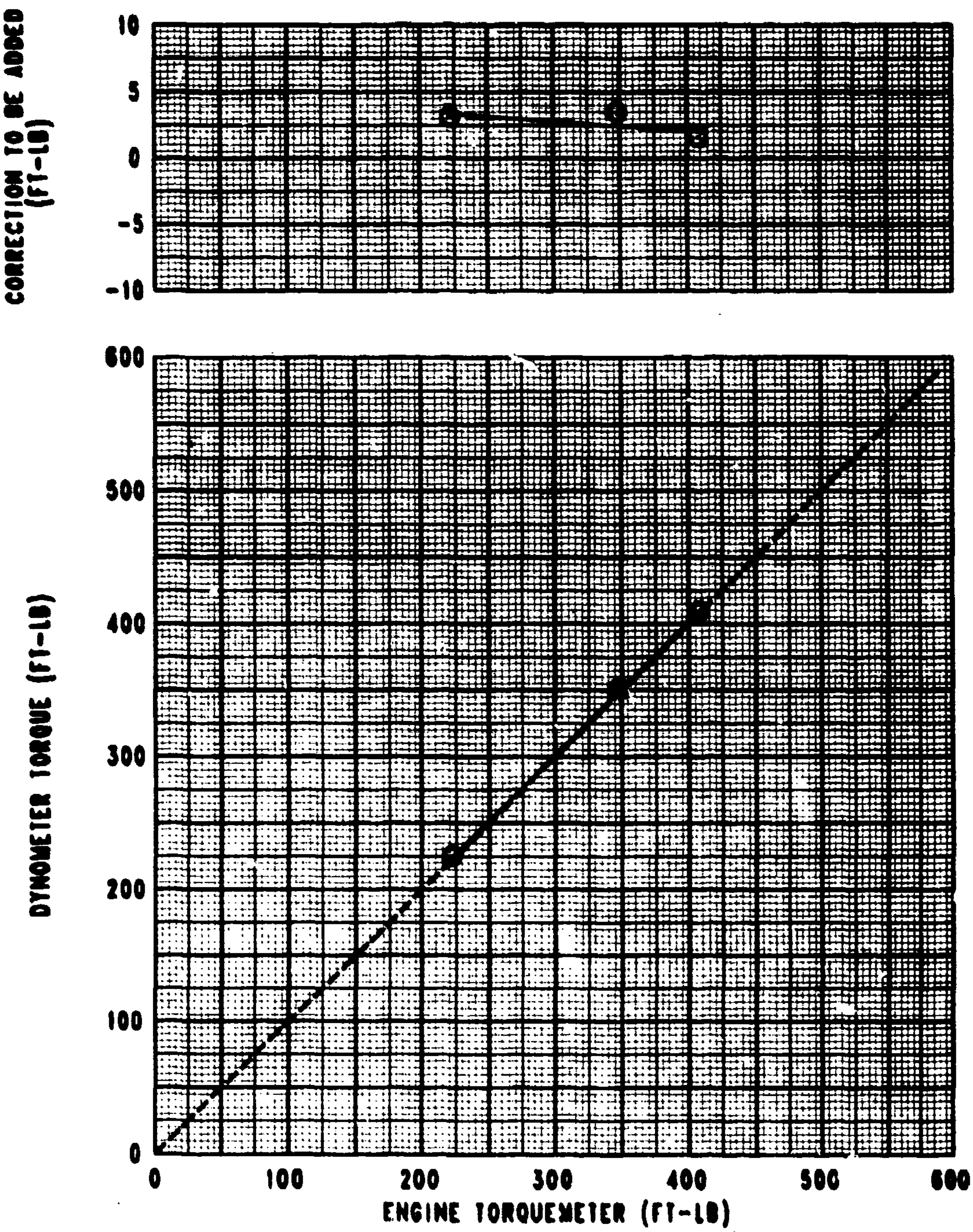


FIGURE 4
ENGINE TORQUEMETER CALIBRATION
UH-60A USA S/N 84-23953
T700-GE-700 S/N 306629

NOTES: 1. NUMBER TWO ENGINE
2. POWER TURBINE SPEED = 20,900 RPM
3. DATA OBTAINED FROM G E
ENGINE PRODUCTION RATING SHEET



4. The test boom airspeed system along with the ship's standard systems were calibrated in level flight using a calibrated trailing bomb to determine the position error. Sikorsky's ground speed course was used to determine the high speed calibration data (above 120 knots indicated airspeed). The position error of the boom airspeed system is presented in figures 1 through 2.

ENGINE CALIBRATION

5. Calibrations of the engine torque sensor systems was conducted by the engine manufacturer, General Electric. Figures 3 and 4 present the calibrations used to determine engine power.

SPECIAL EQUIPMENT

Weather Station

6. A portable weather station consisting of an anemometer, sensitive temperature gauge, relative humidity sensor and barometer, was used to record wind speed, wind direction, ambient temperature and humidity and pressure altitude at 50 feet above ground level.

Ground Pace Vehicle

7. Pace vehicle speedometers were calibrated by Sikorsky personnel. The pace vehicles were used to establish precise ground speed during the low airspeed handling qualities tests.

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

AIRCRAFT RIGGING

1. Prior to the start of testing, a flight controls engineering rigging check was performed on the main and tail rotors by Sikorsky Aircraft and monitored by the U.S. Army Aviation Engineering Flight Activity. The stabilator control system was also checked to ensure compliance with the production stabilator schedule. The rigging data are presented in table 1.

AIRCRAFT WEIGHT AND BALANCE

2. The test aircraft was weighed in both the normal utility configuration and with the VOLCANO system installed, with full oil and all fuel drained, all ballast removed, and test instrumentation system and ballast mounting provisions installed. The initial weight of the aircraft in normal utility configuration was 12,368 pounds with a longitudinal center of gravity (cg) located at fuselage station (FS) 361.4. Installation of the XM-139 VOLCANO mine dispensing system side panels, launcher racks, and 160 full XM-88 mine canisters increased the empty weight of the aircraft by 6530 lbs to a weight of 18,898 lbs with a longitudinal cg at FS 350.8. The fuel weight for each performance test flight was determined by pre- and post-flight aircraft weighings, fuel flowmeter instrumentation, and fuel specific gravity measurements.

PERFORMANCE

General

3. Performance data were obtained using the basic methods described in Army Material Command Pamphlet, AMCP 706-204 (ref 10, app A). Level flight performance and control positions in level flight were obtained in coordinated (ball-centered) flight. Referred rotor speed was maintained constant for all performance tests at 258 rpm. Longitudinal cg was allowed to vary $\pm$1.5 inch during each test flight, but for each data set (consisting of several flights in the same aircraft configuration at different thrust coefficient values) the average cg location was maintained constant near the proposed mission value. The data were analyzed to determine the drag differences between aircraft configurations in terms of change in equivalent flat plate area (Δ Fe).

4. Helicopter performance was generalized through the use of non-dimensional coefficients as follows using the 1968 U.S. Standard Atmosphere:

Table 1. Main and Tail Rotor Rigging Information

Main Rotor Rigging

Flight Control Position				Blade Angle[1] (deg)				Flight Control Position (deg)		
Long	Lat	Coll	Pedal	0	90	180	270	Long Cont[2]	Lat Cont[3]	Coll Cont[4]
Aft	*[5]	*	*		20.0		-4.0	-12.0		
Block[6]	*	*	*		11.1		5.5	- 2.8		
Block	*	High	*	20.0	16.2	11.4	15.0	- 0.6	-4.3	15.7
Block	*	Low	*	2.6	5.3	-1.9	-5.7	- 5.5	-2.3	0.1
Aft	*	High	*		26.8		4.8	-11.0		
Fwd	Left	Low	*	7.7	-12.0	-8.1	11.0	11.5	-7.9	-0.4
Block	*	*	Right		6.7		9.6	1.5		
Block	*	*	Left		15.2		0.3	- 7.5		
Fwd	*	*	Right		-10.0		25.4	17.7		
Aft	Left	*	Left	15.8	19.6	-0.8	-4.5	-12.1	-8.3	7.5
Fwd	Right	*	Left	2.0	-5.2	13.9	20.4	12.8	6.0	7.8
Aft	*	High	Left		26.8		4.3	-11.3		
Fwd	*	High	Right		-1.4		32.2	16.8		
Fwd	Right	High	Left	9.9	-1.6	20.9	32.0	16.8	5.5	15.3
Aft	Left	High	Right	24.0	22.9	8.2	9.1	-6.9	-7.9	16.1
Aft	Right	Low	Right	-6.9	9.8	7.4	-9.9	-9.9	7.2	0.1
Aft	Left	Low	Left	6.9	8.9	-8.5	-10.3	-9.6	-7.7	-0.8

Tail Rotor Rigging

Flight Control Position		Blade Angle (deg)[7]
COLLECTIVE	PEDAL	
*	Left	15.7
*	Right	-15.4
*	*	0.5
Low	*	-7.3
High	Left	15.9
High	Right	-6.1
Low	Right	-15.8
Low	Left	7.4

NOTES:

[1]Measured on the Black Blade at the cuff.
[2]270 degree readiug minus 90 degree reading divided by 2.
[3]180 degree reading minus 0 degree reading divided by 2.
[4]Sum of all four readings divided by 4.
[5]* Indicates appropriate control was pinned at a rigged position.
[6]Indicates a block was inserted between the aft longitudinal control stop and the cyclic control such that no limiters are contacted to determine longitudinal to collective coupling.
[7]Measured on the Blue Blade at the cuff.

a. Coefficient of Power (C_P):

$$C_P = \frac{SHP\ (550)}{\rho A(\Omega R)^3} \quad (1)$$

b. Coefficient of Thrust (C_T):

$$C_T = \frac{GW}{\rho A(\Omega R)^2} \quad (2)$$

c. Advance Ratio (μ):

$$\mu = \frac{V_T(1.6878)}{\Omega R} \quad (3)$$

Where:

SHP = Engine output shaft horsepower (both)
ρ = Ambient aft density ($lb\text{-}sec^2/ft^4$)
A = Main rotor disc area = 2262.03 ft^2
Ω = Main rotor angular velocity (radians/sec)
R = Main rotor radius = 26.833 ft
GW = Gross weight (lb)

$$V_T = \text{True airspeed (kt)} = \frac{V_E}{1.6878\sqrt{\rho/\rho_o}}$$

1.6878 = Conversion factor (ft/sec/kt)
ρ_o = 0.0023769 ($lb\text{-}sec^2/ft^4$)

5. The engine output shaft torque was determined by use of engine torque sensors. The power turbine shaft contains a torque sensor tube that mechanically displays the total twist of the shaft. A concentric reference shaft is secured by a pin at the front end of the power turbine drive shaft and is free to rotate relative to the power turbine shaft at the rear end. The relative rotation is due to transmitted torque, and the resulting phase angle between the reference teeth on the two shafts is picked up by the torque sensor. This torque sensor was calibrated in a test cell by the engine manufacturer. The output from the engine torque sensor was recorded by the on-board data recording system.

The output SHP was determined from the engine's output shaft torque and rotational speed by the following equation.

$$SHP = \frac{2\pi\, Q(N_p)}{33,000} \qquad (4)$$

Where:

Q = Engine output shaft torque (ft-lb)
N_p = Engine output shaft rotational speed (rpm)

Level Flight Performance

6. Each speed power data set was flown in ball-centered flight by reference to the ship's turn and slip indicators at a predetermined thrust coefficient (C_T) and referred rotor speed ($N_R/\sqrt{\theta}$). Both the pilot's and copilot's turn and slip indicators were checked for alignment with the aircraft positioned in a level attitude on the ground. To maintain the ratio of gross weight to pressure ratio (W/δ) constant, altitude was increased as fuel was consumed. To maintain $N_R/\sqrt{\theta}$ constant, rotor speed was varied as appropriate for the ambient air temperature. Corrections to power required were made for the installation of test instrumentation. The power consumption for the electrical operation of the instrumentation equipment was measured and determined to be 0.76 shp and subtracted from the power required data. The effects of the external instrumentation and nonstandard aircraft equipment were estimated by the contractor to be the equivalent of 3.04 square feet of equivalent flat plate area.

7. The non dimensional coefficients (equations 1 through 3) can be expressed in terms of referred rotor speed as follows:

$$C_P = \frac{SHP\ (478935.3)}{\delta\sqrt{\theta}\left(\dfrac{N_R}{\sqrt{\theta}}\right)^3 (\rho_0 A R^3)} \qquad (5)$$

$$C_T = \frac{GW\ (91.19)}{\delta \left(\frac{N_R}{\sqrt{\theta}}\right)^2 (\rho_0 A R^2)} \tag{6}$$

$$\mu = \frac{V_T\ (16.12)}{(R\sqrt{\theta}) \left(\frac{N_R}{\sqrt{\theta}}\right)} \tag{7}$$

Test-day level flight data were corrected to standard day conditions by the following equations:

$$SHP_s = SHP_t \left(\frac{P_s}{P_t}\right)\left(\frac{N_{R_s}}{N_{R_t}}\right) \tag{8}$$

$$V_{T_s} = V_{T_t} \left(\frac{N_{R_s}}{N_{R_t}}\right) \tag{9}$$

Where:

Subscript t = Test day
Subscript s = Standard day

$$\delta = \text{Pressure ratio} = \left(1 - \frac{H_P}{145442.15}\right)^{5.255863}$$

$$\theta = \text{Temperature ratio} = \frac{T_A + 273.15}{288.15}$$

T_A = Ambient air temperature (°C)
N_R = Main rotor speed (rev/min)
478935.3 = Conversion factor (ft-lb-sec^2-rev^3/min^3-SHP)
91.19 = Conversion factor (sec^2-rev^2/min^2)
$\rho = \rho_0 \times \sigma$

$\sigma = \delta/\theta$
16.12 = Conversion factor (ft-rev/min-kt)

Test data corrected for instrumentation electrical power consumption and corrected to standard altitude and ambient temperature are presented in figures 4 through 9, appendix E.

8. Changes in equivalent flat plate area calculated from changes in engine power coefficient were determined using the following equation:

$$\Delta F_e = \frac{\Delta C_p(2A)}{\mu^3} \qquad (10)$$

Where:

ΔF_e = Change in equivalent flat plate area (ft^2)

The data obtained in the normal utility configuration were analyzed by use of a simulated three dimensional plot (C_T and μ versus C_p). The reduction of this simulated three dimensional plot to a family of curves of C_T versus C_p, for a constant μ value, allows determination of the power required as a function of airspeed for any value of C_T. The data obtained in both aircraft configurations were compared to determine change in the equvalent flat plate area using equation 10.

9. Analysis of the level flight performance data in the normal utility configuration defined the basic performance curves (figs. 1 through 3, app E). Applying the ΔF_e technique to these curves to produce a consistent fit to the VOLCANO configuration data (figs. 7 through 9, app E) required the ΔF_e values to change with thrust coefficient and airspeed, as shown in figure 1. The baseline ΔF_e shown here as a function of C_T applies to a level aircraft pitch attitude, which occurred at 47 KCAS. Since aircraft pitch attitude varied as a function of calibrated airpseed and was consistent for all values of C_T flown (figs. 13 through 15), a percentage adjustment to the baseline ΔF_e could be obtained by calculating increase in projected frontal area of the VOLCANO system resulting from pitch attitude change. This projected area variation was solely based on geometric considerations resulting by tilting a rectangle that approximated the proportional dimensions of the VOLCANO system (assumed 50 unit height and 65 unit base). The percentage of ΔF_e adjustment as a function of calibrated airspeed shown in figure 1 was added to the baseline ΔF_e using the expression:

$$\Delta F_e = (1.0 + \text{percent } \Delta F_e \text{ increase}/100.) \times \Delta F_{e_{baseline}} \qquad (11)$$

HANDLING QUALITIES

10. Handling qualities data were evaluated using standard test methods described in Naval Air Test Center Flight Test Manual, FTM No. 101 (ref 11). A Handling Qualities Rating Scale (HQRS) (fig. 2) was used to augment pilot comments relative to aircraft handling qualities.

VIBRATIONS

11. A Vibration Rating Scale (fig. 3) was used to augment pilot comments relative to aircraft vibrations.

DEFINITION

12. Results were categorized as shortcomings in accordance with the following definition.

Shortcoming: An imperfection or malfunction occurring during the life cycle of equipment, which must be reported and which should be corrected to increase efficiency and to render the equipment completely serviceable. It will not cause an immediate breakdown, jeopardize safe operation, or materially reduce the usability of the material or end product.

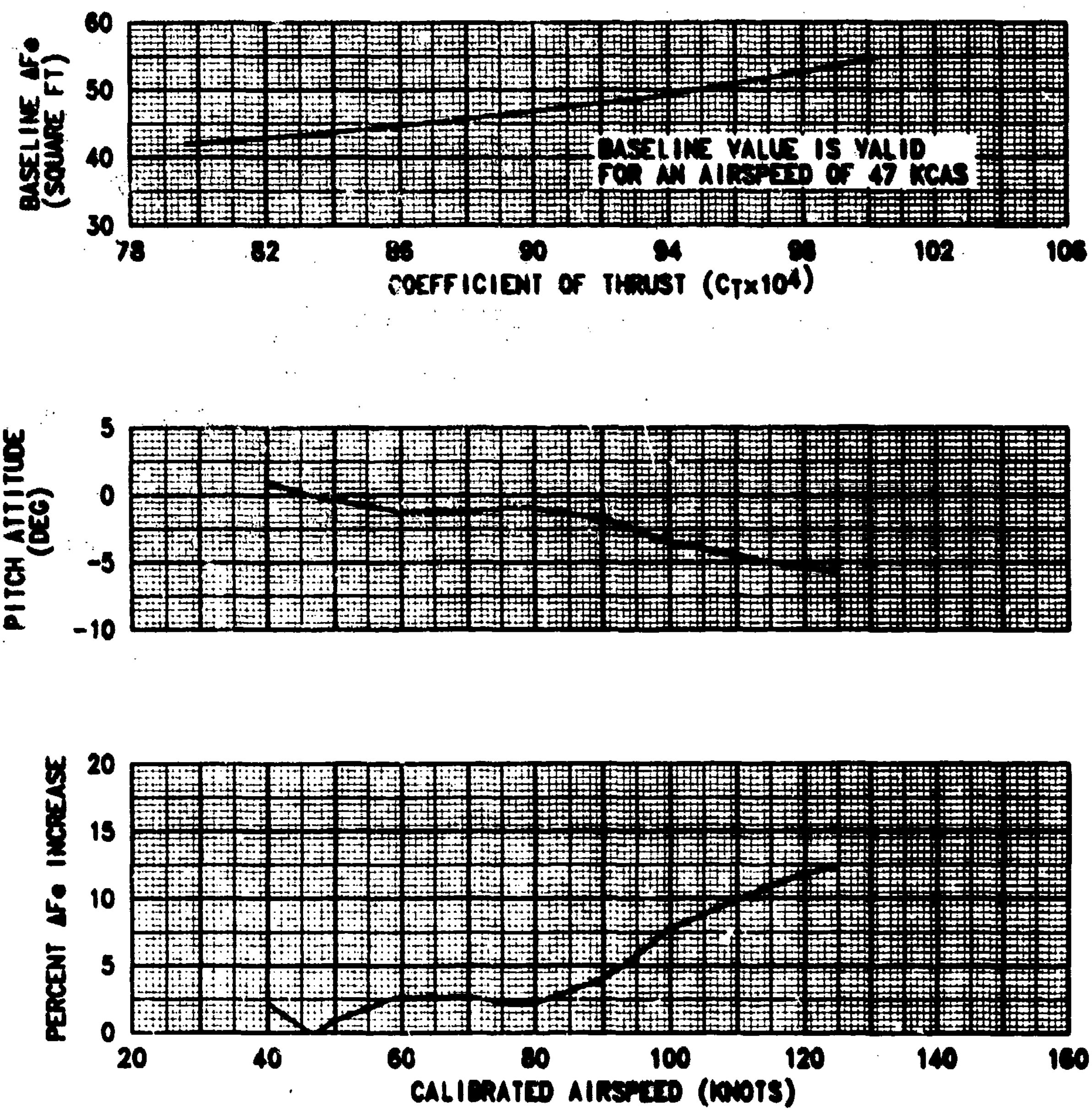
FIGURE 1

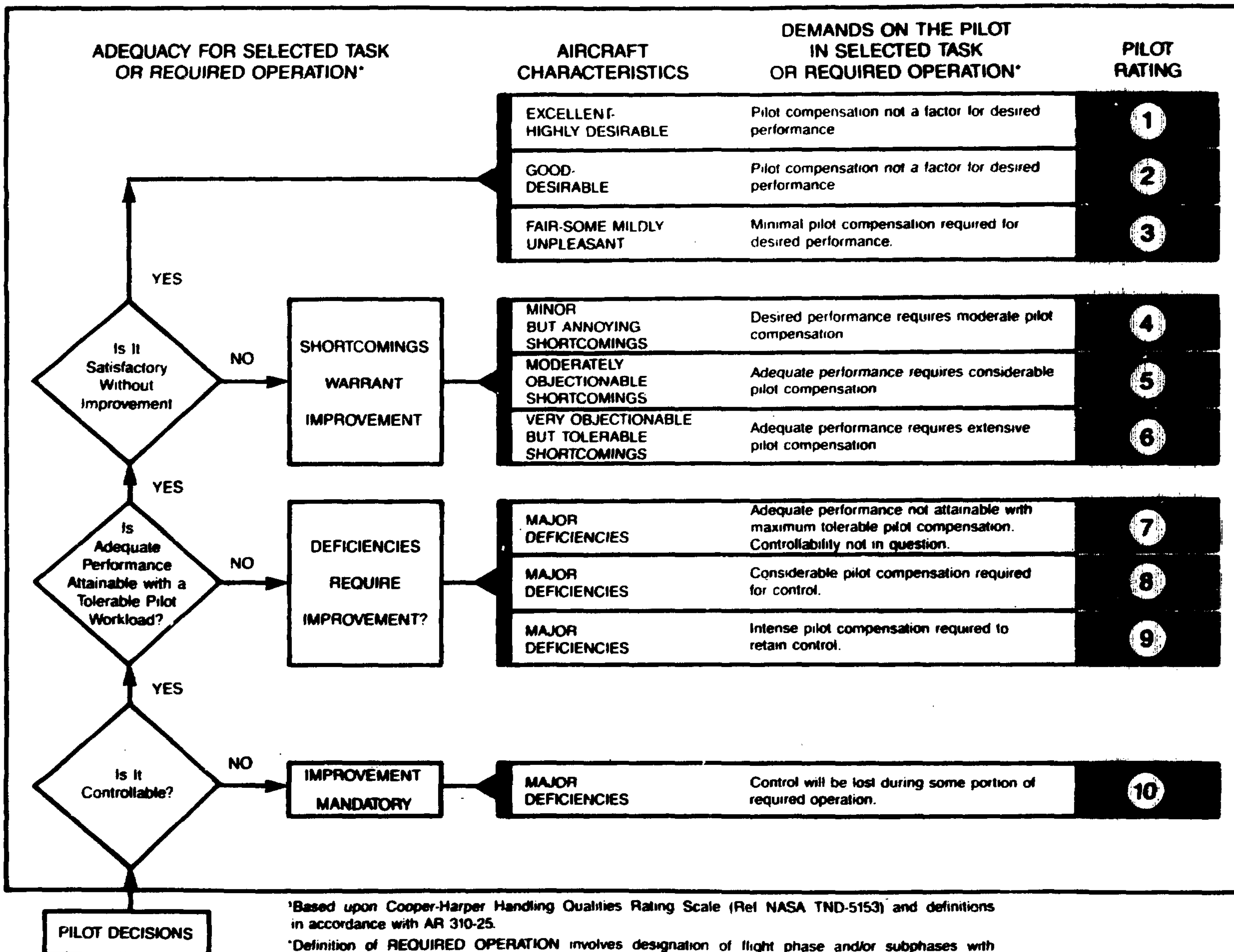
CHANGE IN ΔFe WITH AIRSPEED AND GROSS WEIGHT

UH-60A USA S/N 84-23953

NOTES:
1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. REFERRED MAIN ROTOR SPEED=258 RPM

BASELINE ΔFe OF VOLCANO INSTALLATION OVER NORMAL UTILITY CONFIGURATION APPLIES TO LEVEL AIRCRAFT ATTITUDE. PERCENT INCREASE IN ΔFe WITH AIRSPEED IS BASED ON GEOMETRIC CONSIDERATIONS AS PITCH ATTITUDE CHANGES AND IS VALID FOR ALL THRUST COEFFICIENTS.





*Based upon Cooper-Harper Handling Qualities Rating Scale (Ref NASA TND-5153) and definitions in accordance with AR 310-25.

*Definition of REQUIRED OPERATION involves designation of flight phase and/or subphases with accompanying conditions.

Figure 2. Handling Qualities Rating Scale

DEGREE OF VIBRATION	DESCRIPTION[1]	PILOT RATING
No vibration		0
Slight	Not apparent to experienced aircrew fully occupied by their tasks, but noticeable if their attention is directed to it or if not otherwise occupied.	1 2 3
Moderate	Experienced aircrew are aware of the vibration but it does not affect their work, at least over a short period.	4 5 6
Severe	Vibration is immediately apparent to experienced aircrew even when fully occupied. Performance of primary task is affected or tasks can only be done with difficulty.	7 8 9
Intolerable	Sole preoccupation of aircrew is to reduce vibration level.	10

[1]Based on the Subjective Vibration Assessment Scale developed by the Aeroplane and Armament Experimental Establishment, Boscombe Down, England.

Figure 3. Vibration Rating Scale

APPENDIX E. TEST DATA

INDEX

FIGURE 1
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION
3. MID LONGITUDINAL AND LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
5. POINTS DERIVED FROM FIGURES 4 THRU 6

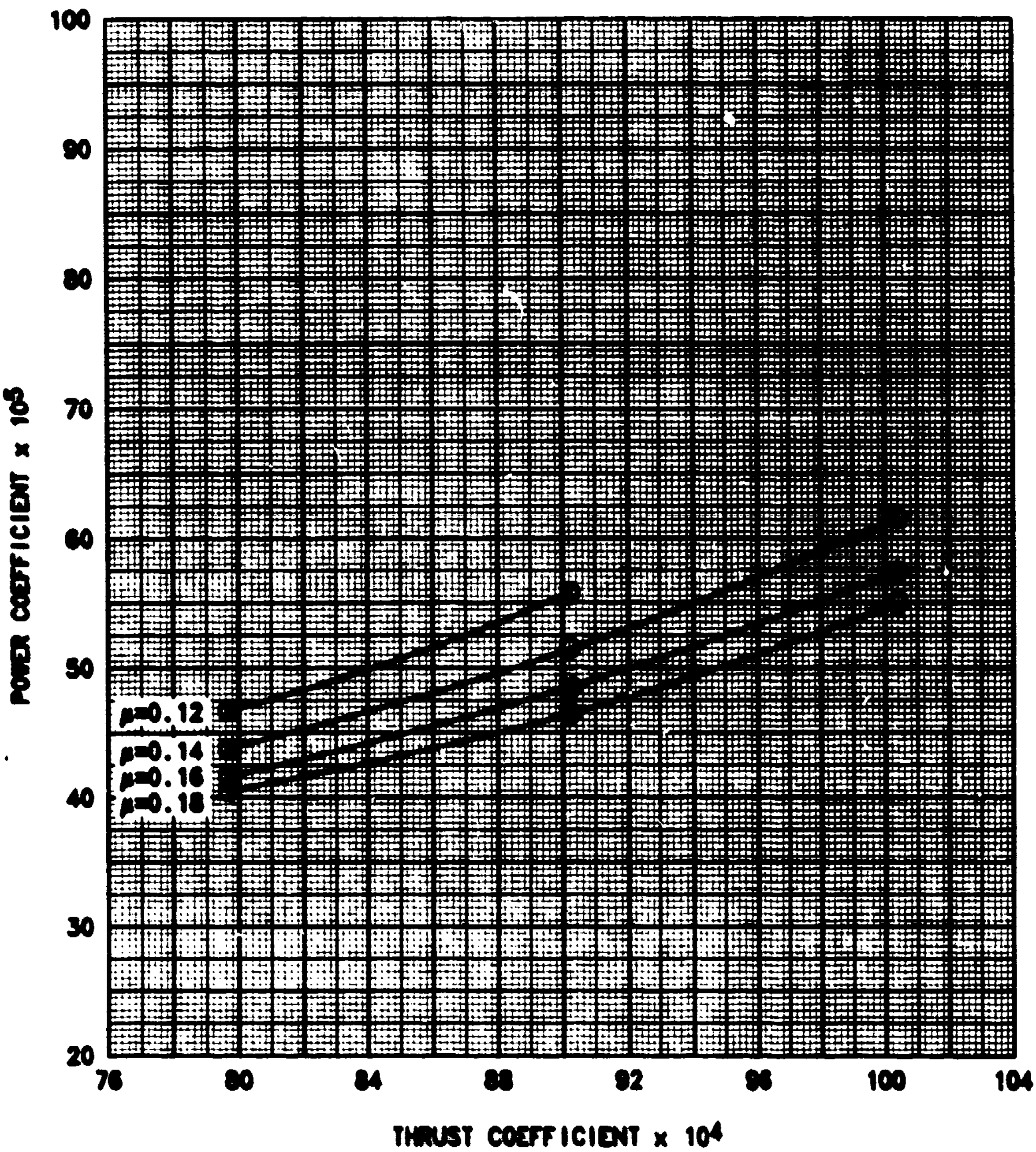


FIGURE 2
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

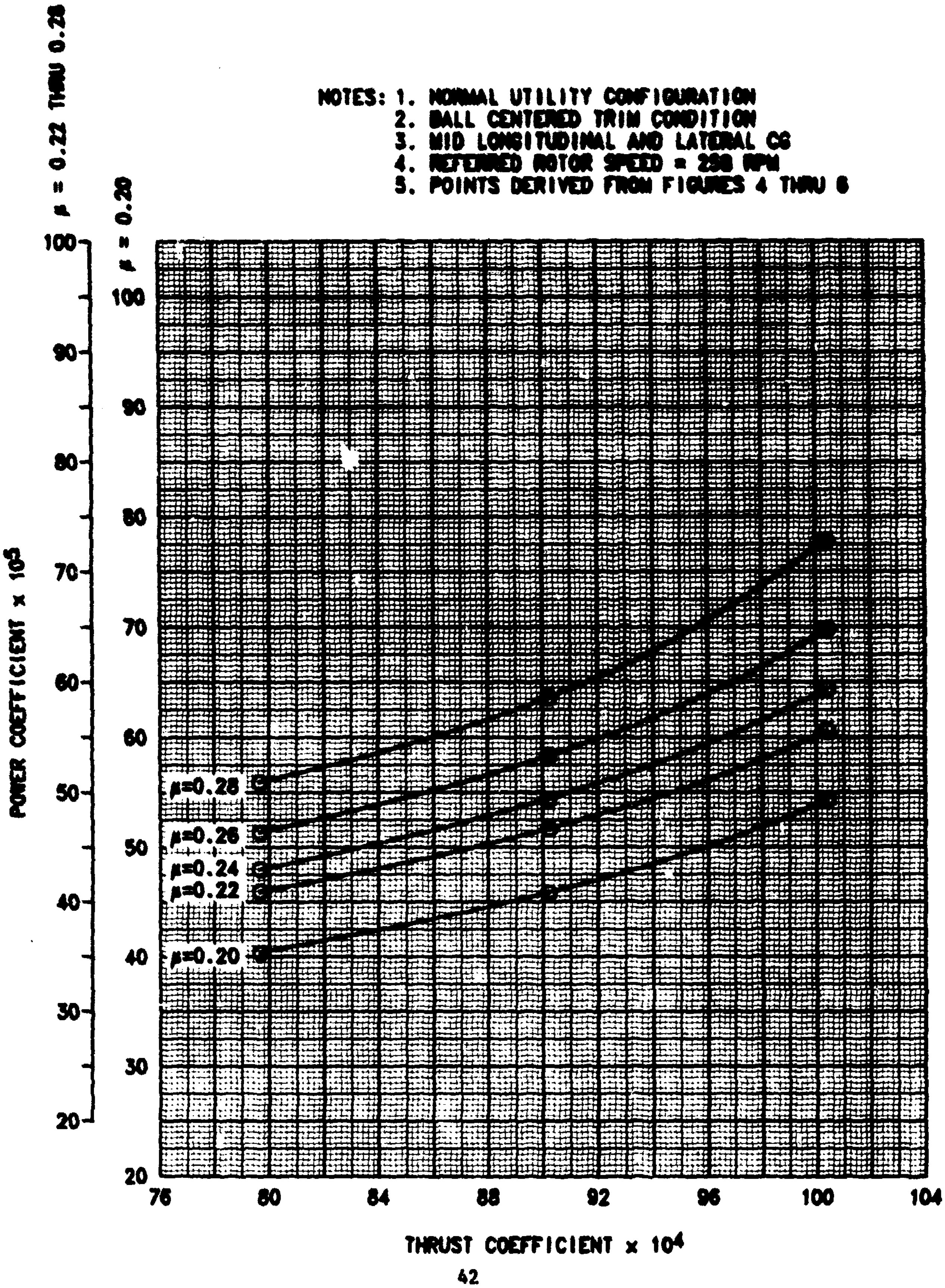


FIGURE 3
NONDIMENSIONAL LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION
3. MID LONGITUDINAL AND LATERAL CG
4. REFERRED ROTOR SPEED = 258 RPM
5. POINTS DERIVED FROM FIGURES 4 THRU 6

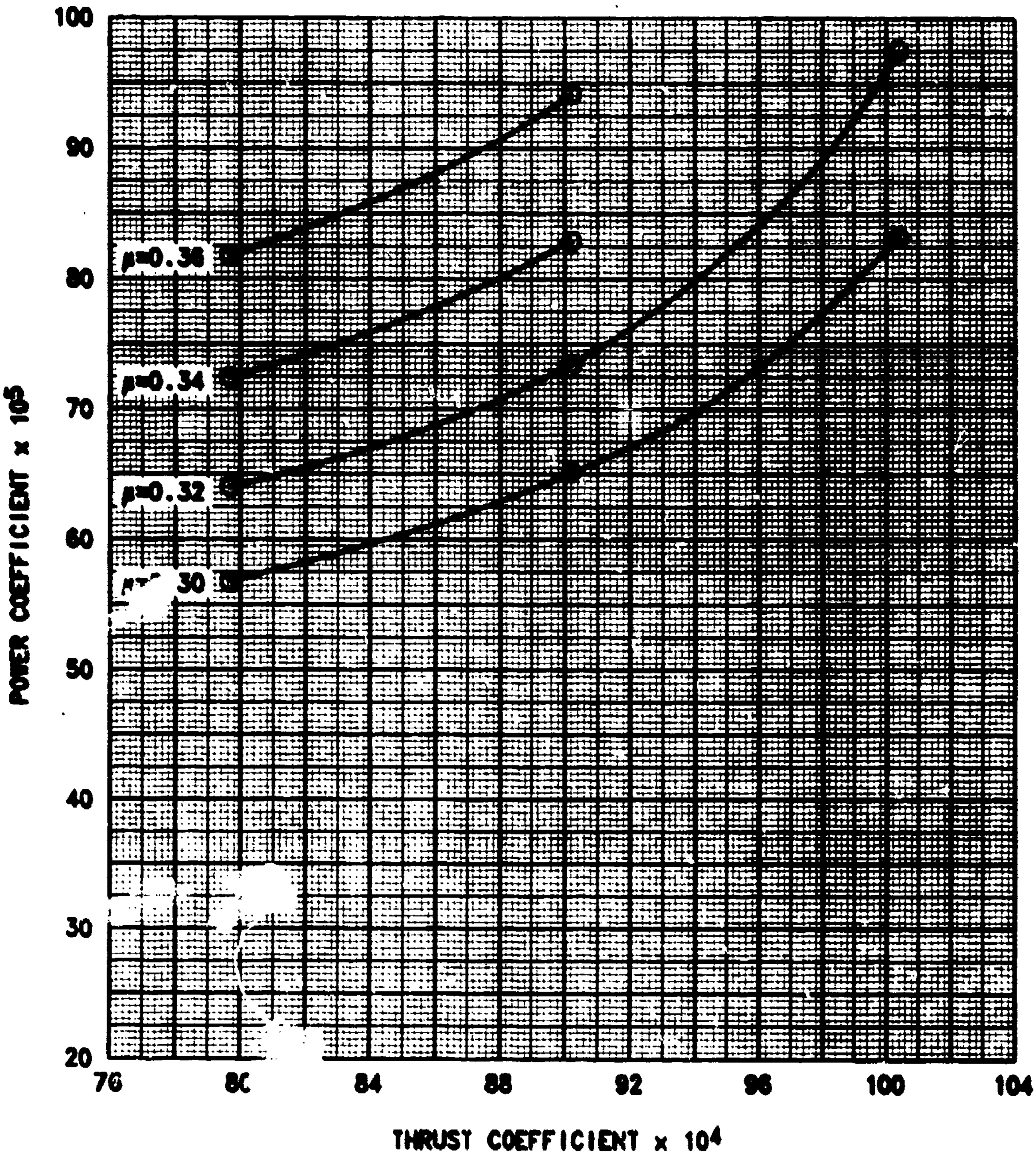


FIGURE 4
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
17720	350.4	0.2	7930	13.5	258.5	0.007966

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

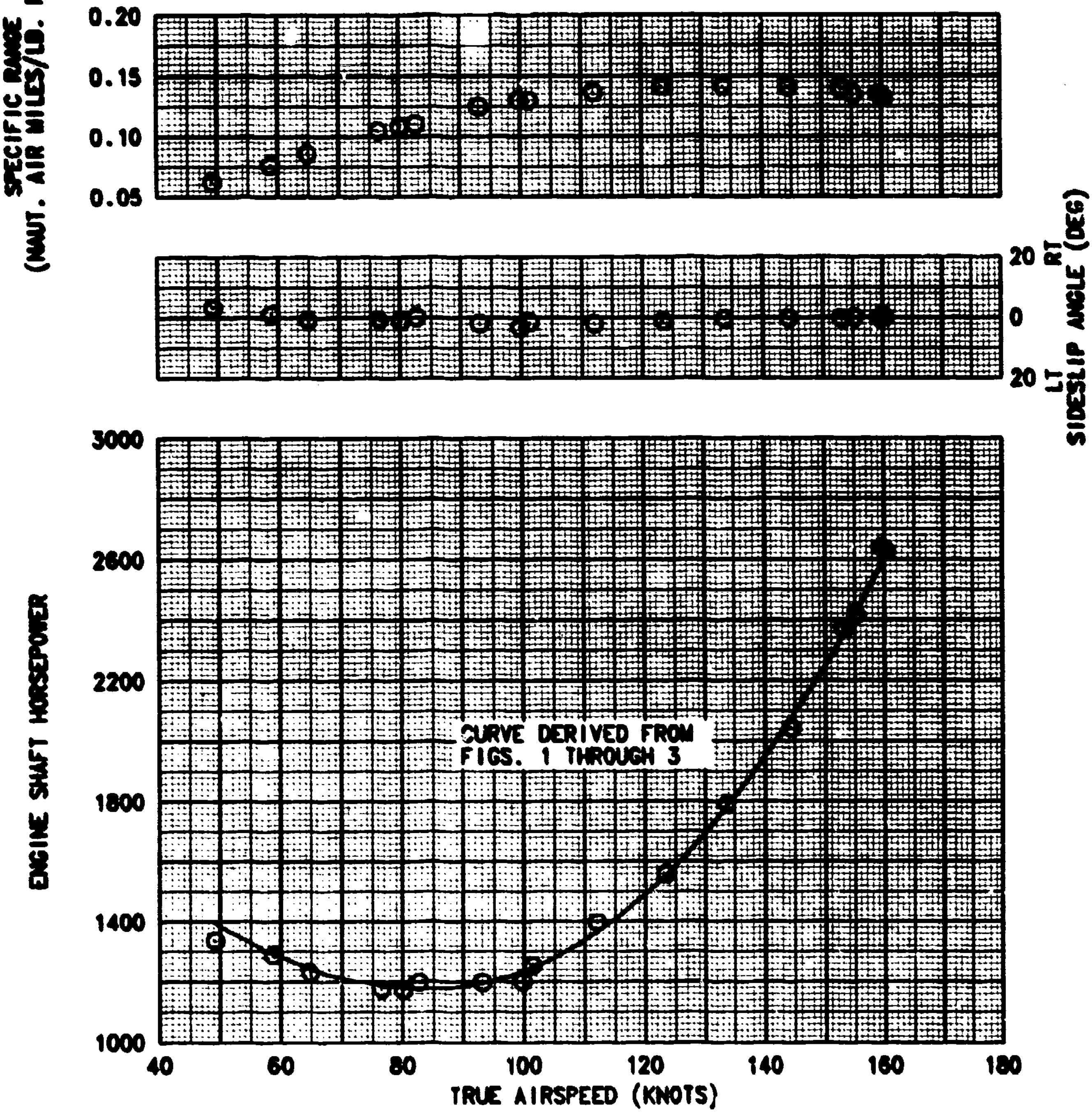


FIGURE 5
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
17840	350.9	0.2	10870	8.5	257.6	0.009022

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

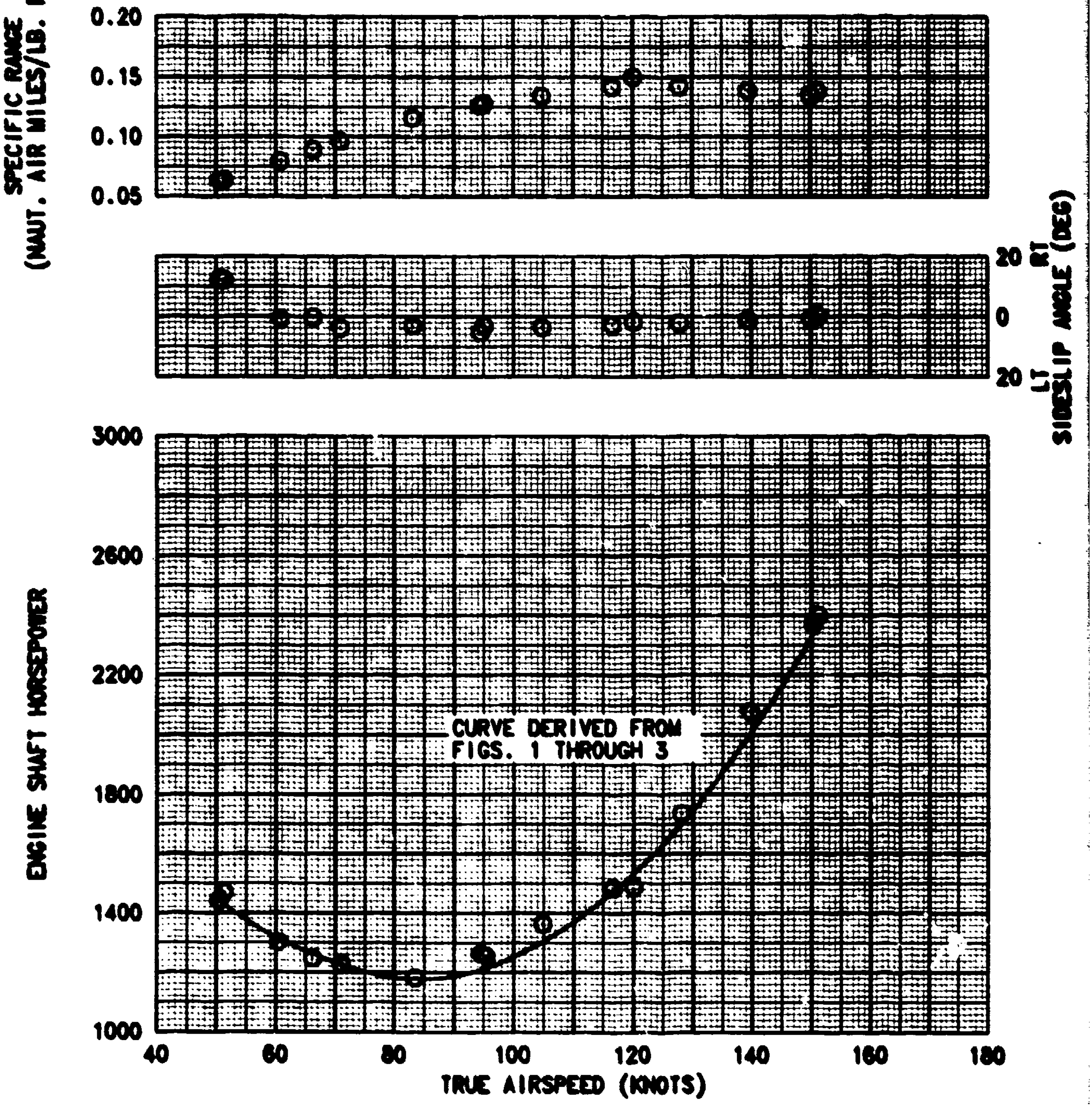


FIGURE 6

LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
17820	350.9	0.2	13290	0.5	257.2	0.010040

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. BALL CENTERED TRIM CONDITION

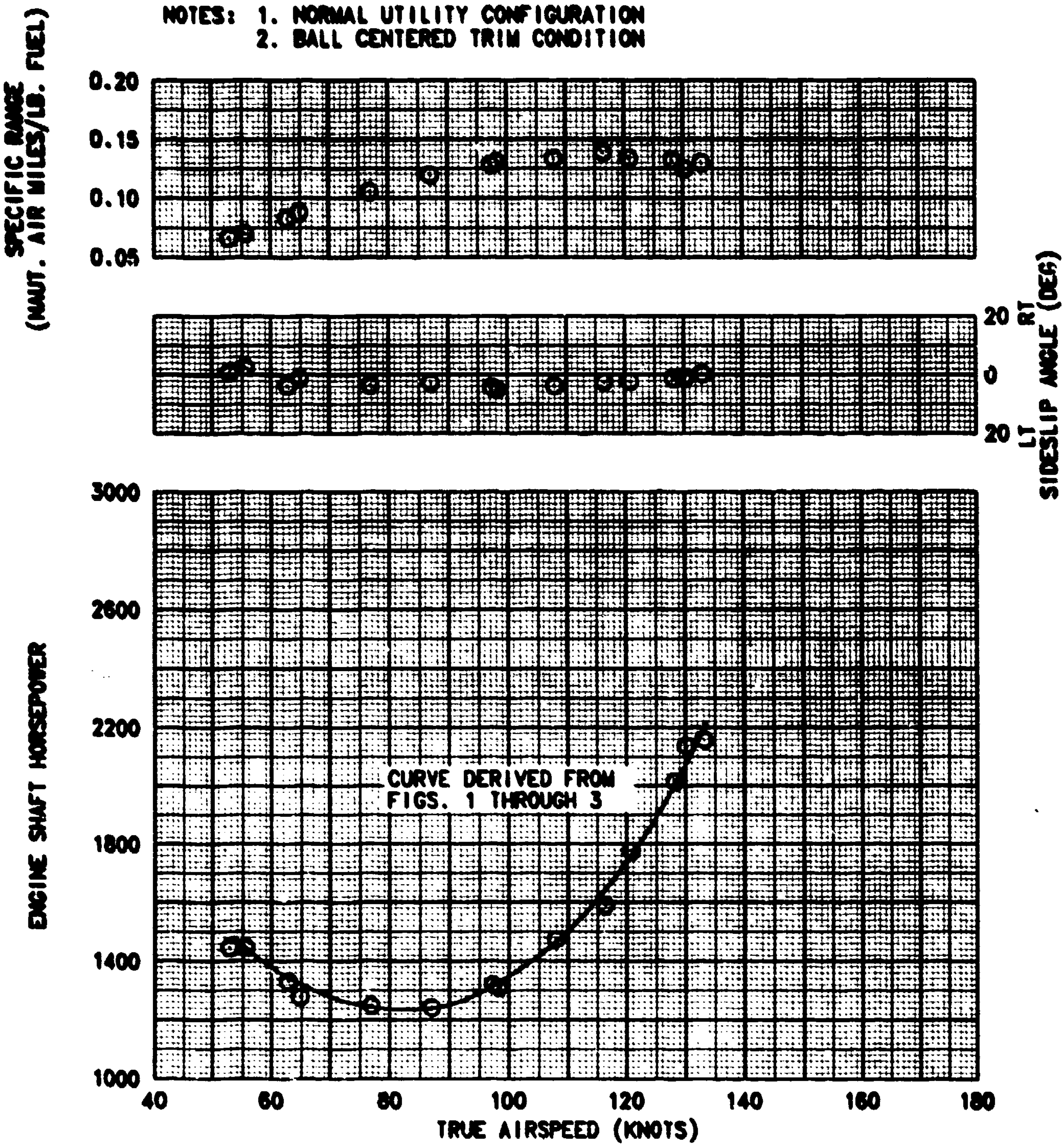


FIGURE 7
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
20450	350.7	0.2	3010	12.0	258.2	0.007985

NOTES:
1. VOLCANO CONFIGURATION
2. BALL CENTERED TRIM CONDITION

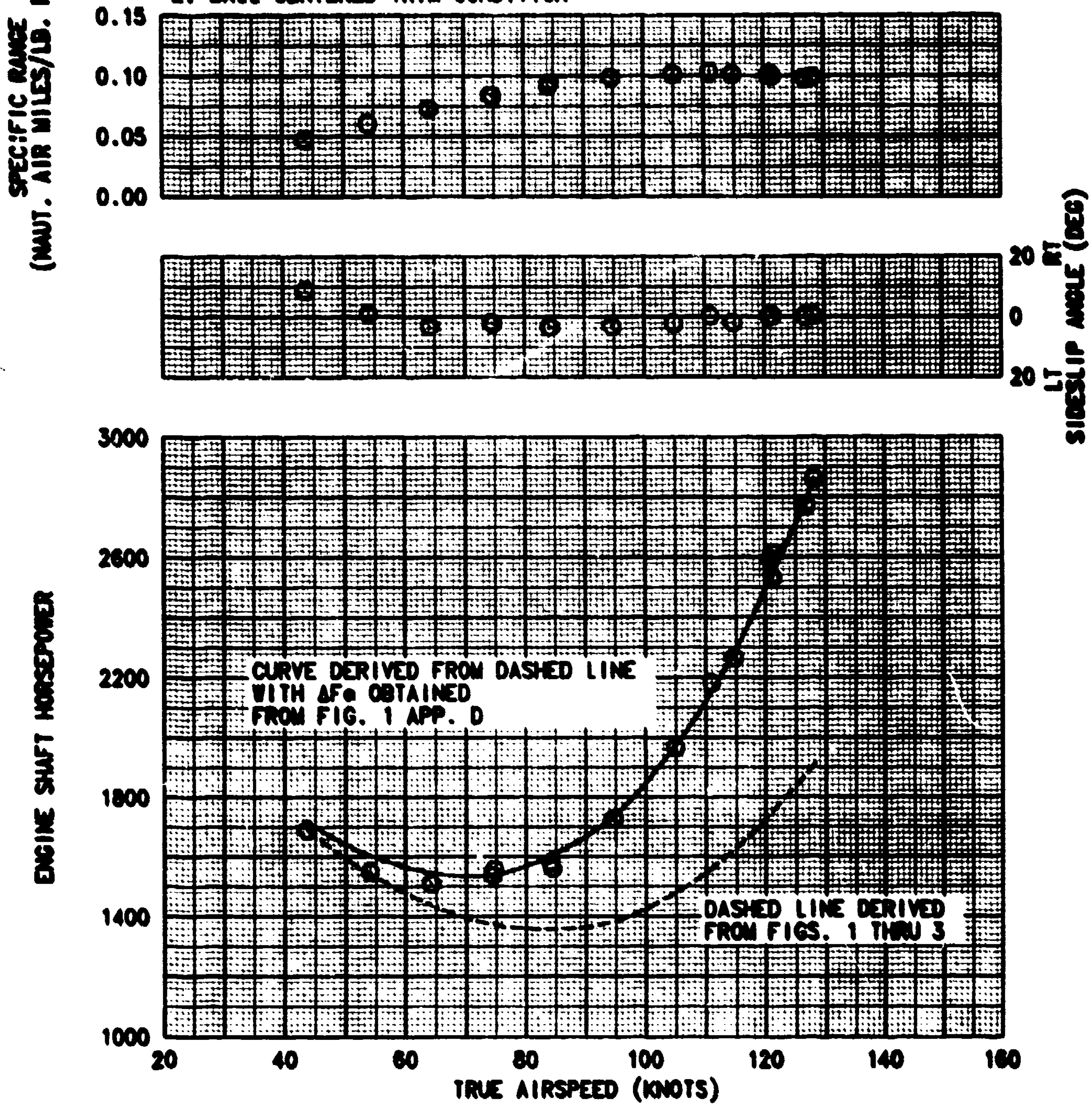


FIGURE 8
LEVEL FLIGHT PERFORMANCE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
20500	350.7	0.2	6260	7.5	257.9	0.008998

NOTES:
1. VOLCANO CONFIGURATION
2. BALL CENTERED TRIM CONDITION

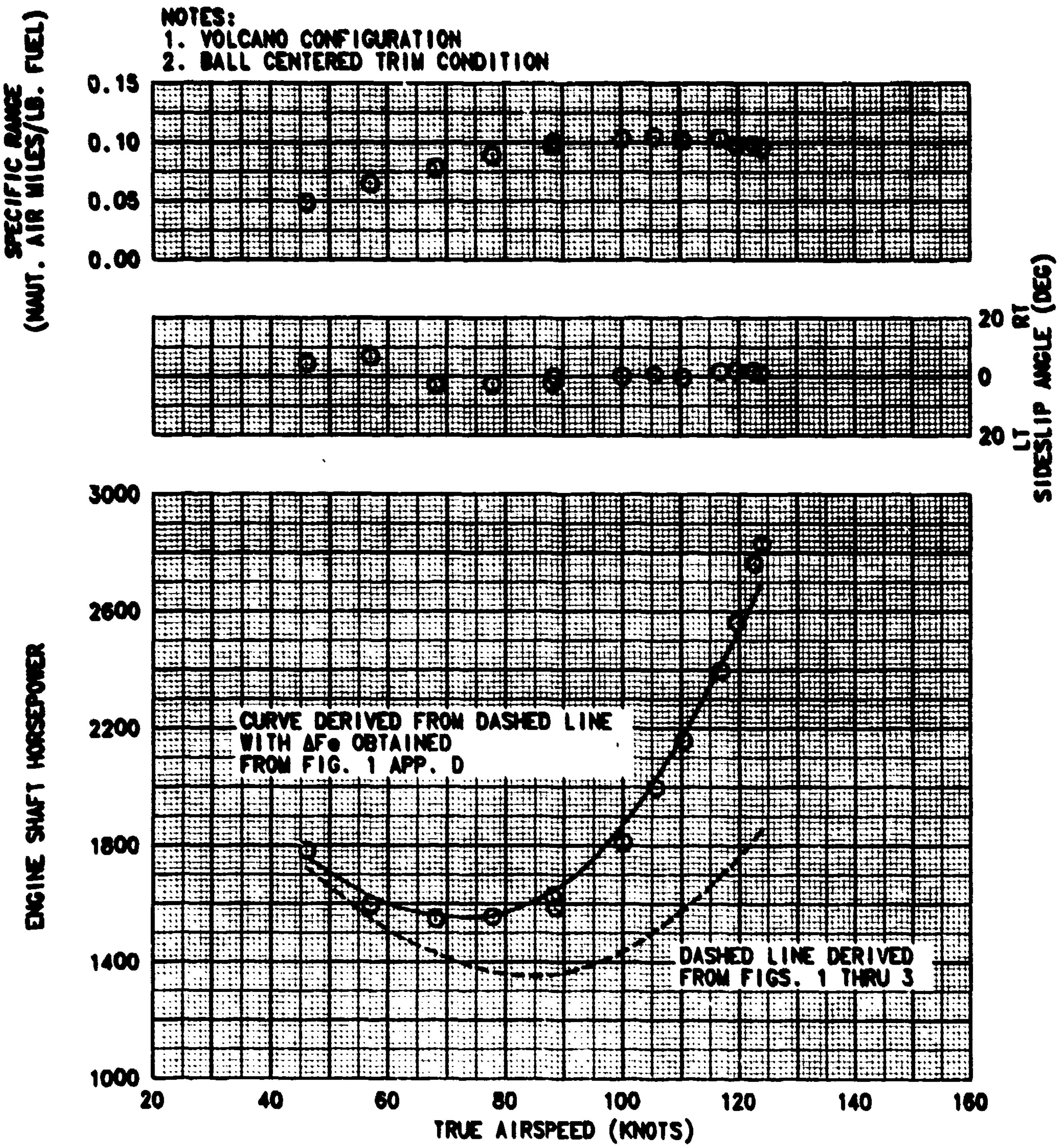


FIGURE 9

LEVEL FLIGHT PERFORMANCE

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	AVG REFERRED ROTOR SPEED (RPM)	AVG COEFFICIENT OF THRUST
20650	351.2	0.2	9330	6.0	258.0	0.009996

NOTES:
1. VOLCANO CONFIGURATION
2. BALL CENTERED TRIM CONDITION

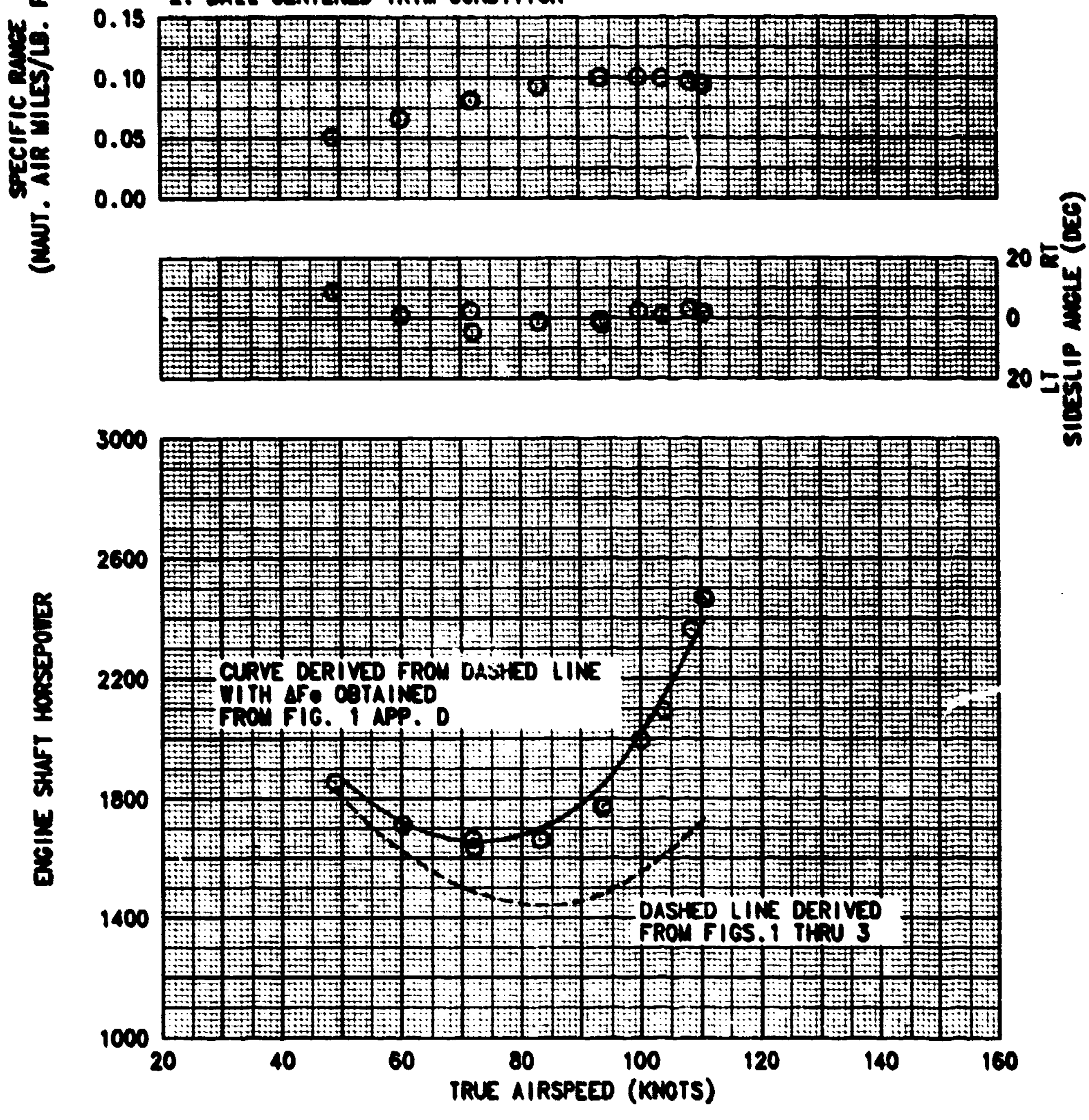


FIGURE 10

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
17720	350.4 MID	0.3LT	7930	13.5	258	.007986	NORMAL UTILITY

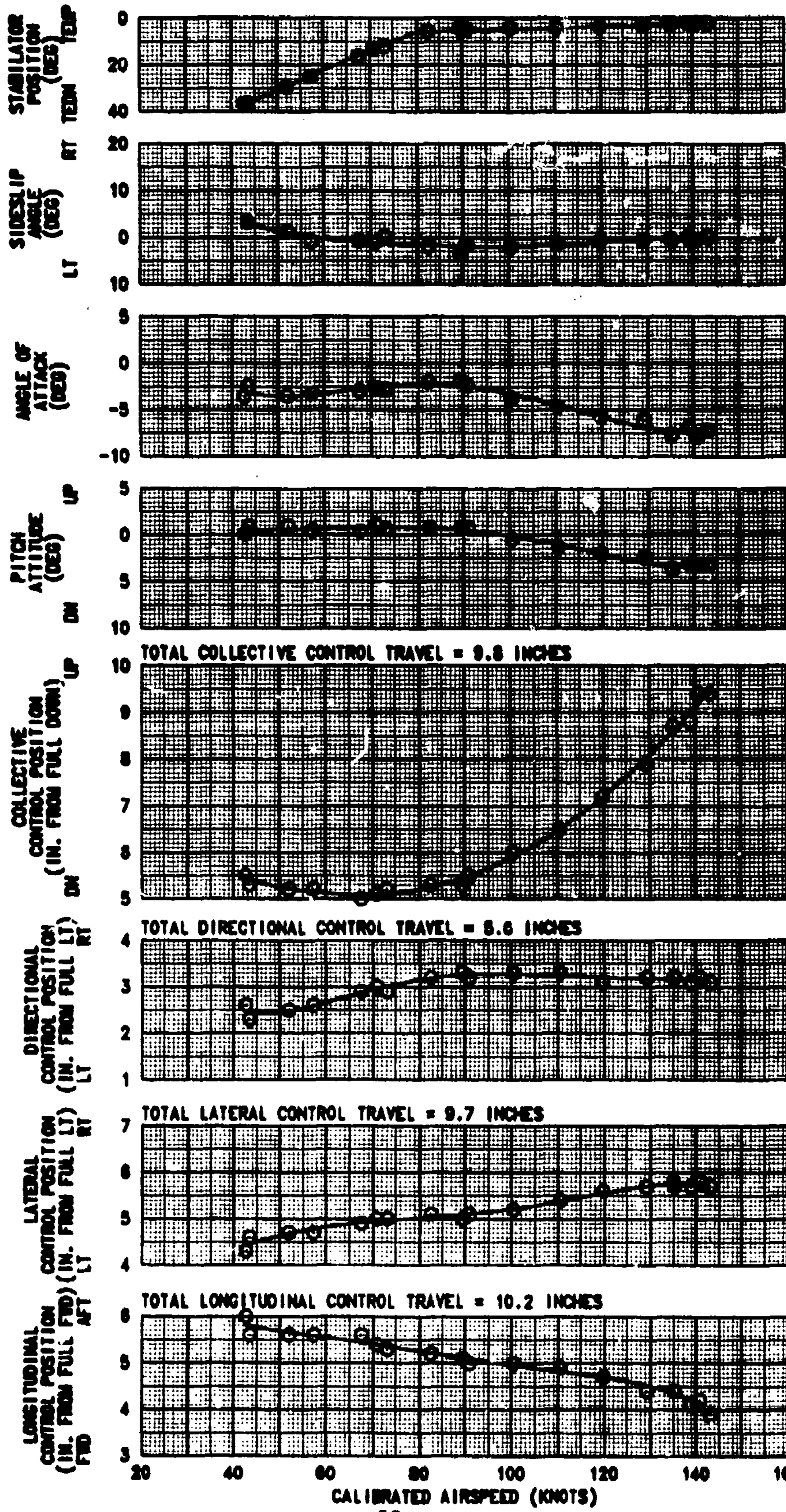


FIGURE 11

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
17840	350.9 MID	0.3LT	10870	8.5	255	.008022	NORMAL UTILITY

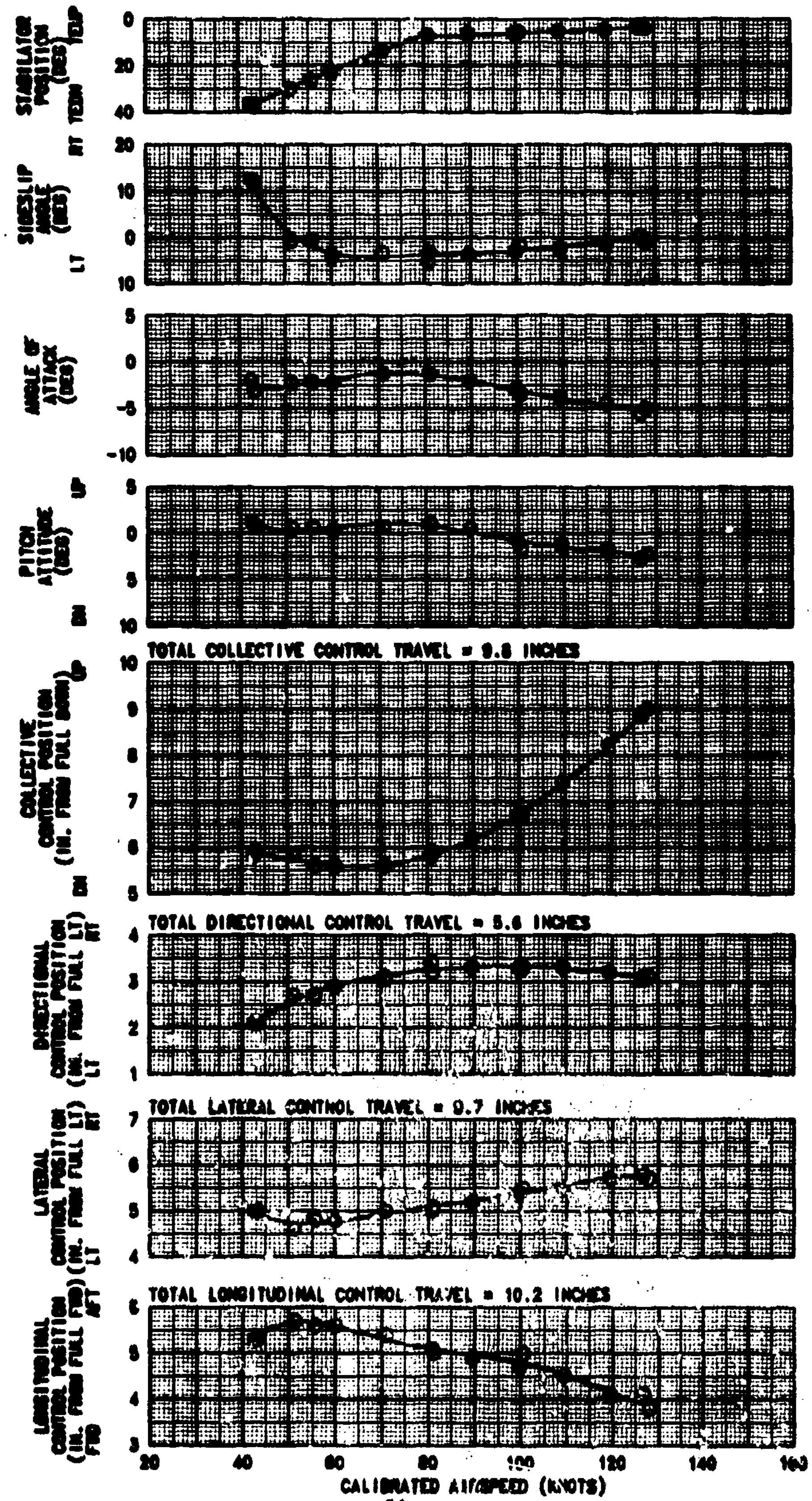


FIGURE 12

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
17820	350.9 MID	0.3LT	13290	0.5	251	.010040	NORMAL UTILITY

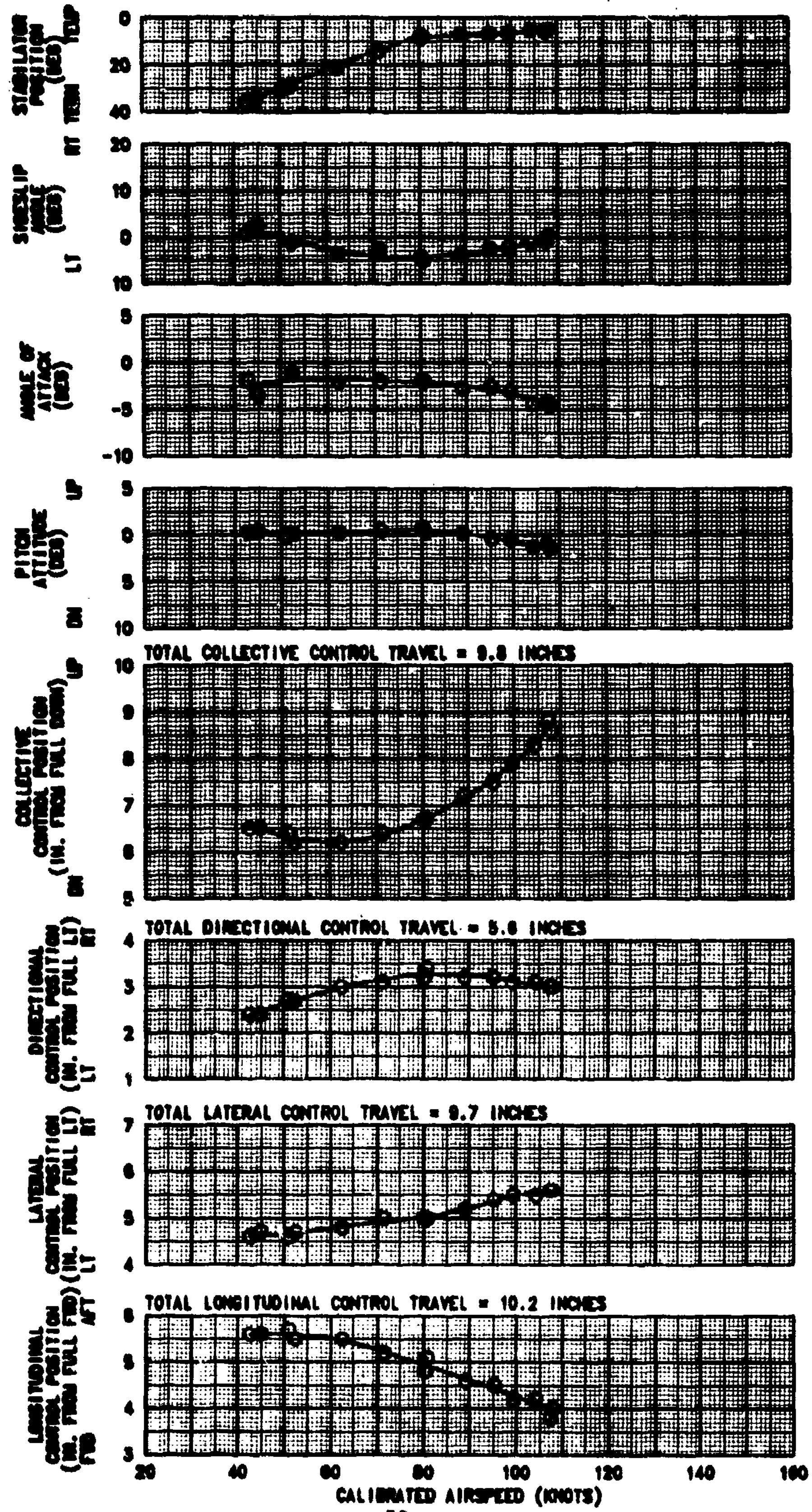


FIGURE 13
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
20450	350.7MID	0.3LT	3010	12.0	257	.007985	VOLCANO

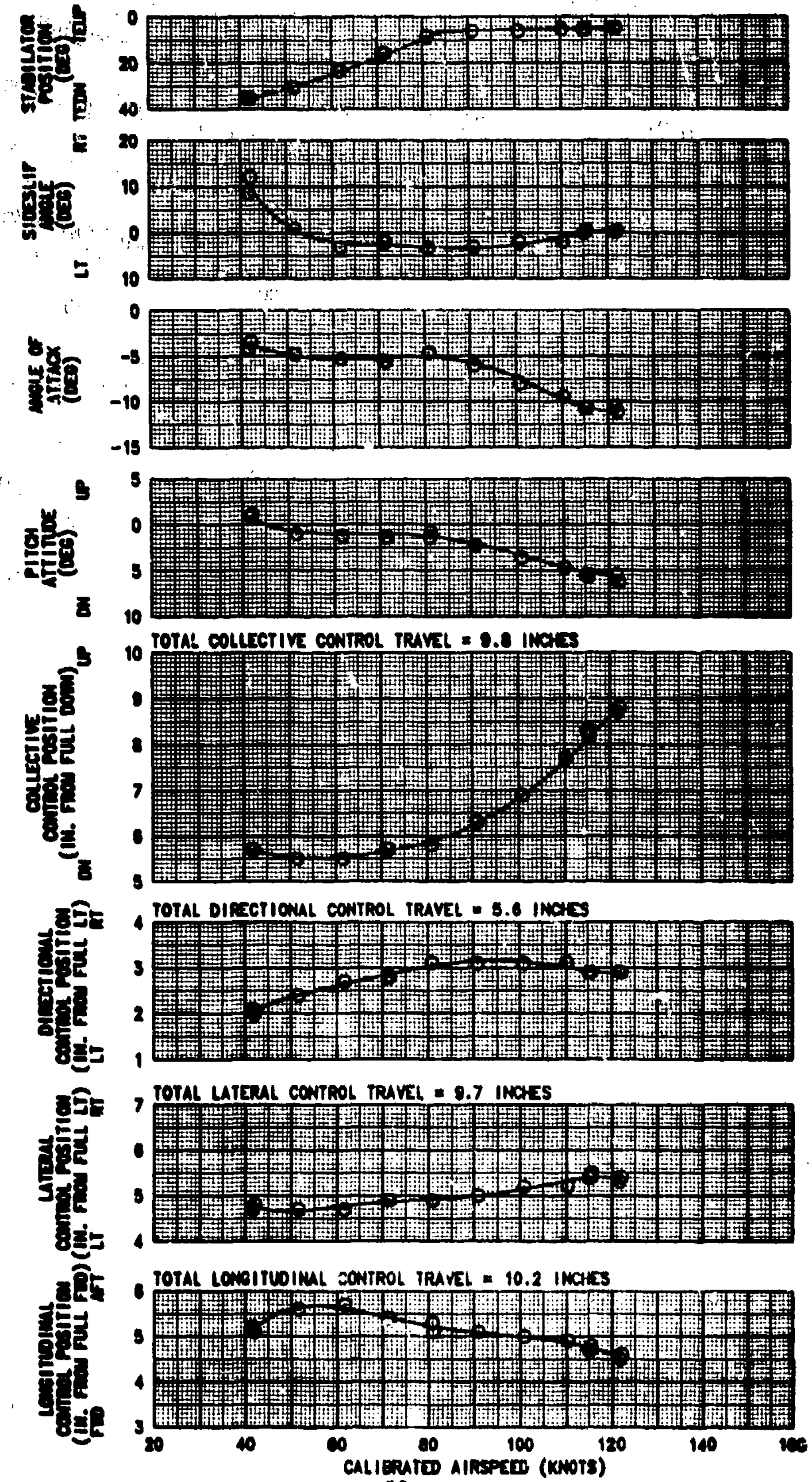


FIGURE 14

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
20000	350.7MID	0.3LT	6200	7.5	255	.006608	VOLCANO

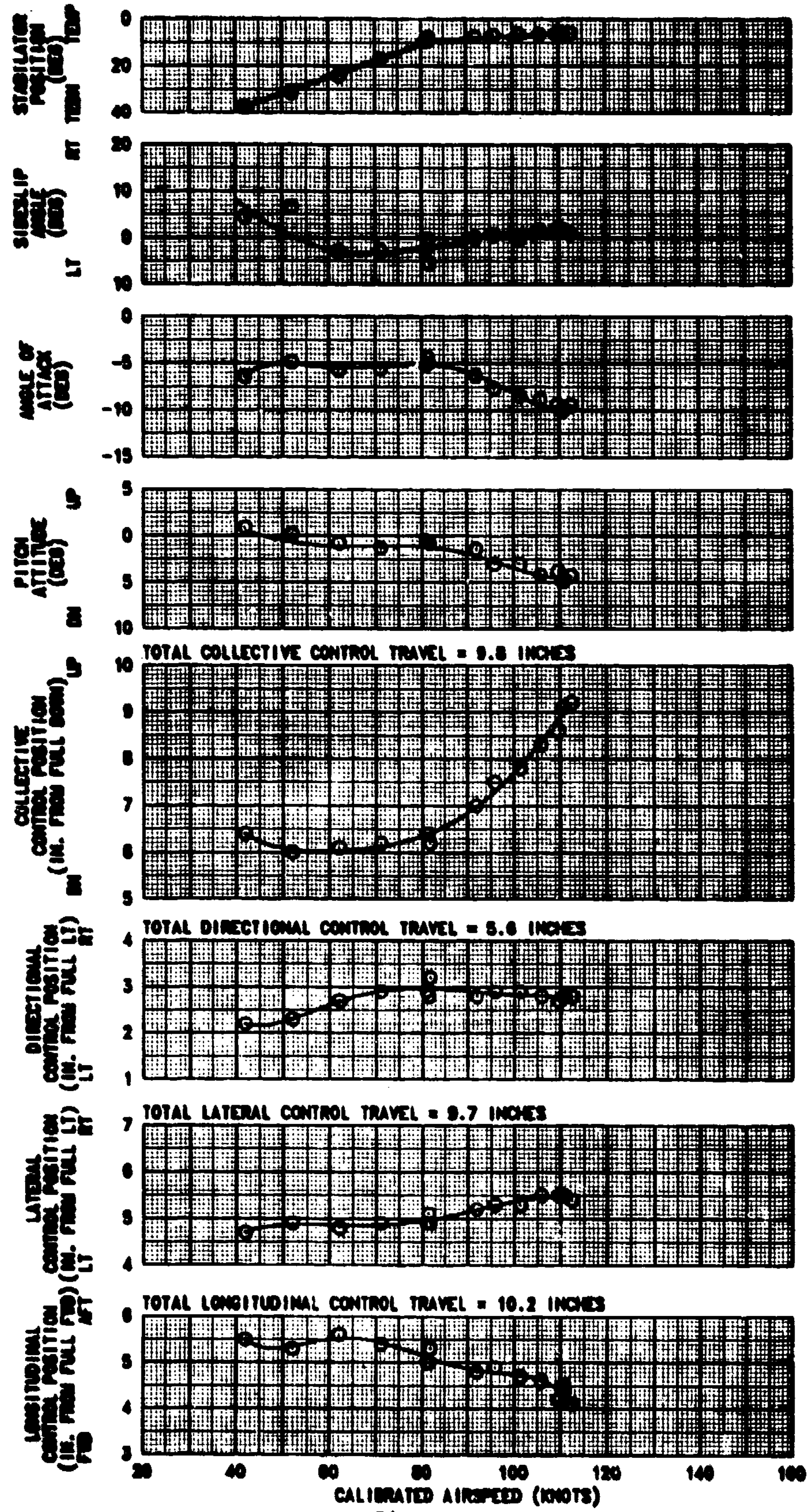


FIGURE 15

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

UH-60A USA S/N 84-23963

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG THRUST COEFF.	AIRCRAFT CONFIGURATION
20880	351.2 MID	0.3 LT	8336	6.0	254	.009068	VOLCANO

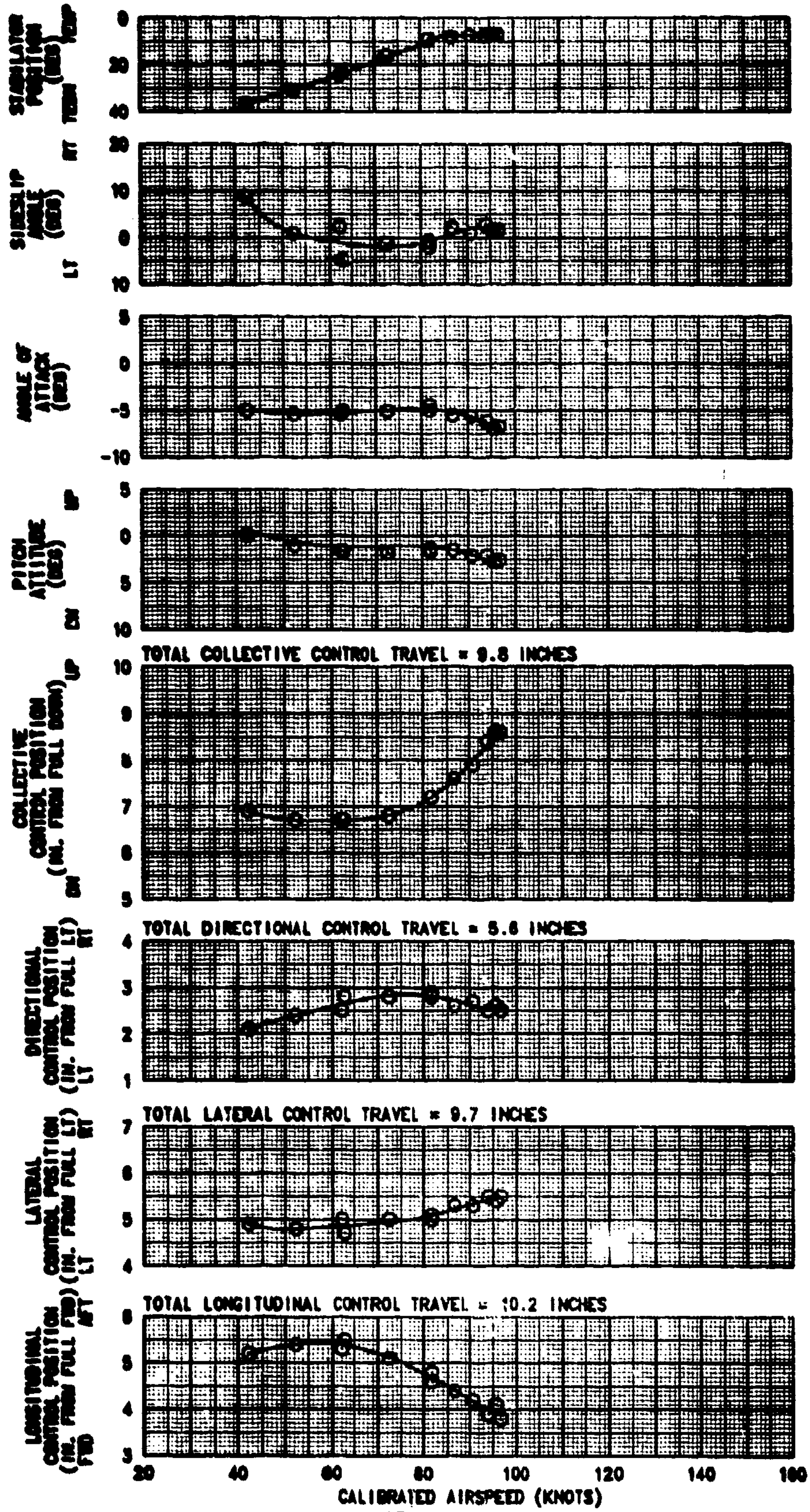


FIGURE 16

COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY

UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
□	20830	351.8MID	0.3 LT	5000	14.0	258	81
○	20550	350.9MID	0.3 LT	4970	14.0	258	118

NOTE:
1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. BALL-CENTERED FLIGHT
5. PBA CENTERED AND LOCKED

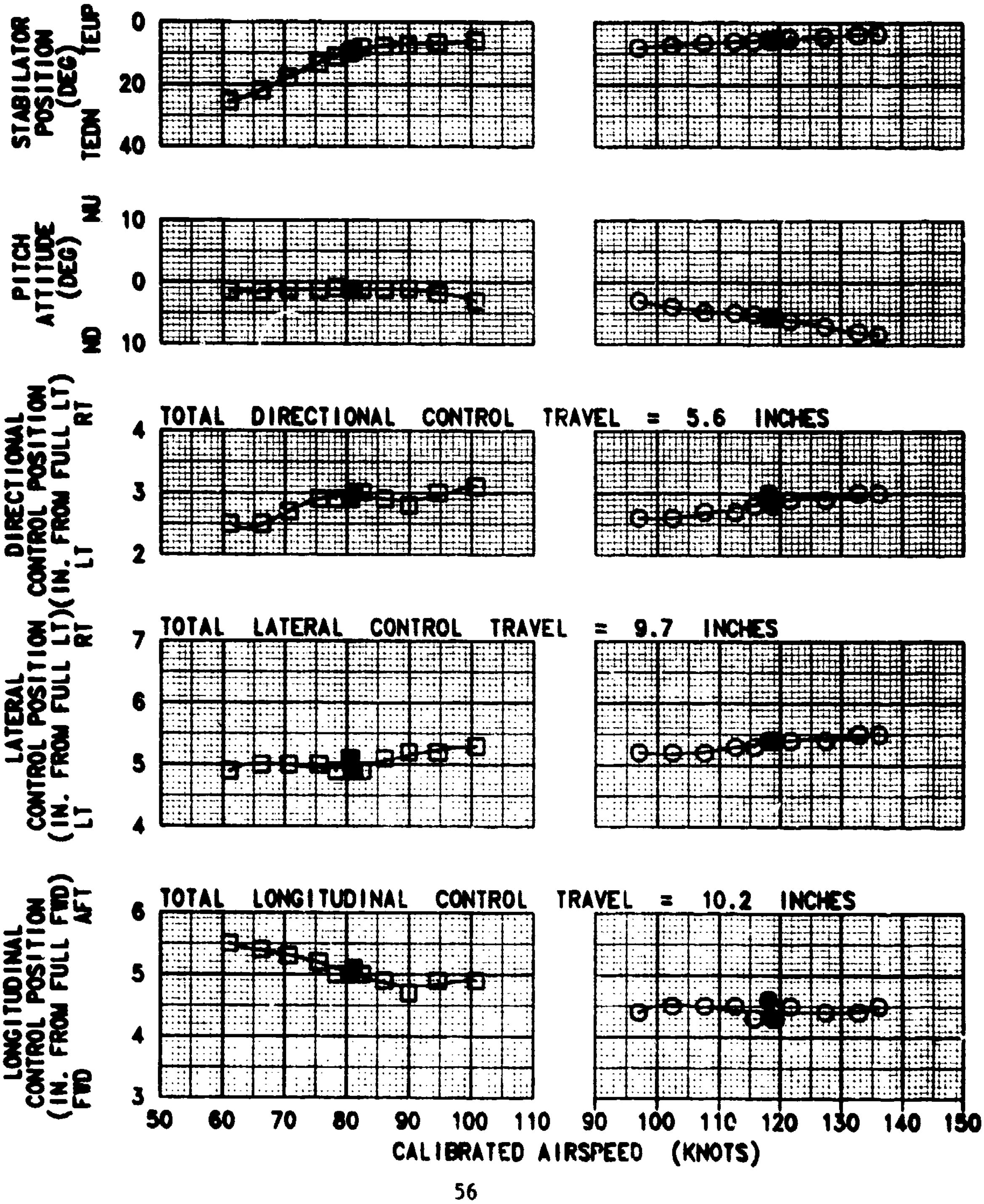


FIGURE 17

COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20700	351.4MID	0.3 LT	5140	15.0	258	82

NOTE:
1. VOLCANO CONFIGURATION
2. IRP CLIMB
3. SHADED SYMBOLS DENOTE TRIM POINT
4. BALL-CENTERED FLIGHT
5. PBA CENTERED AND LOCKED

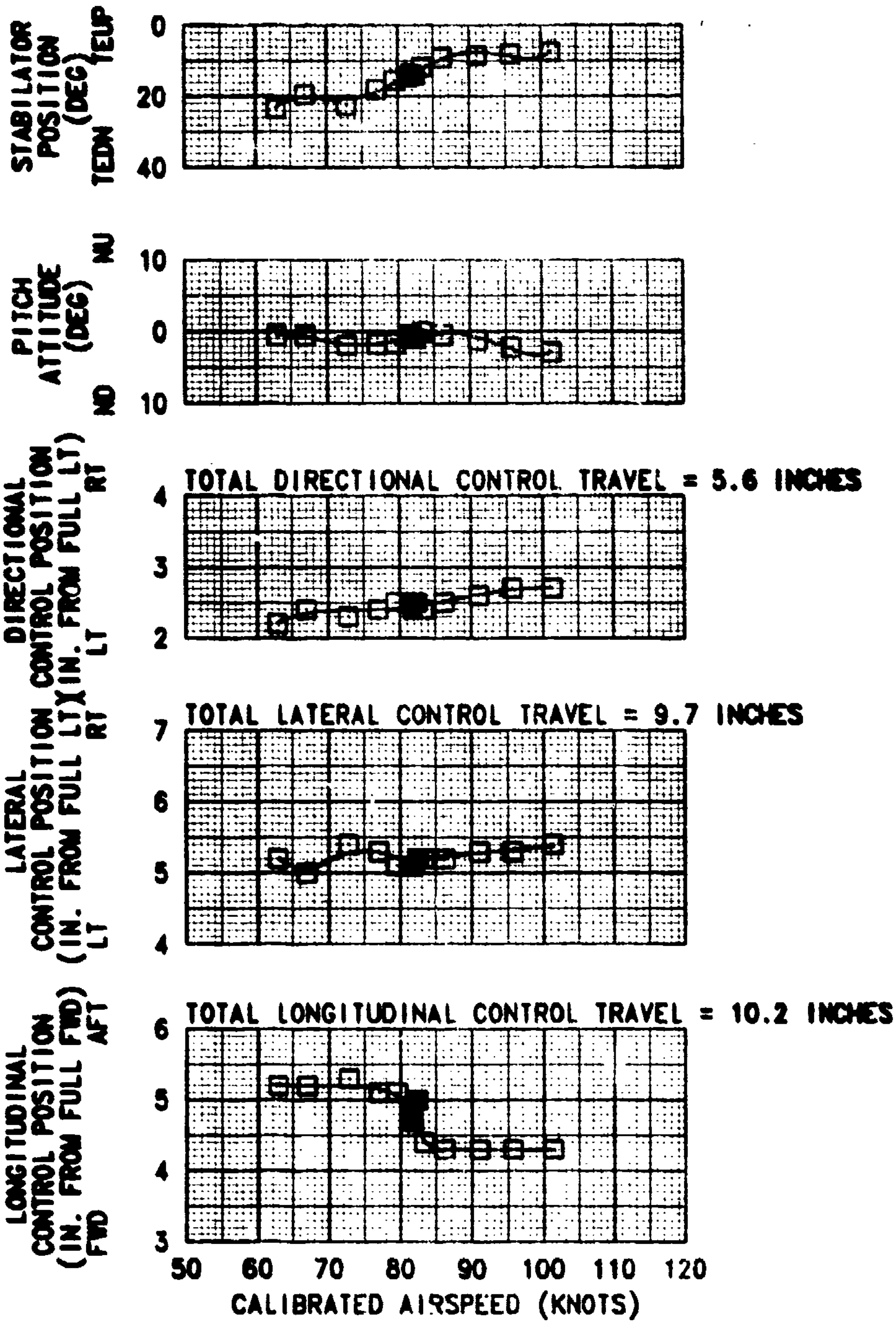


FIGURE 18
COLLECTIVE-FIXED STATIC LONGITUDINAL STABILITY
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)		AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20650	351.2	MID	0.3 LT	4850	15.5	258	83

NOTE:
1. VOLCANO CONFIGURATION
2. 1000 FT. PER MIN. DESCENT
3. SHADED SYMBOLS DENOTE TRIM POINT
4. BALL-CENTERED FLIGHT
5. PBA CENTERED AND LOCKED

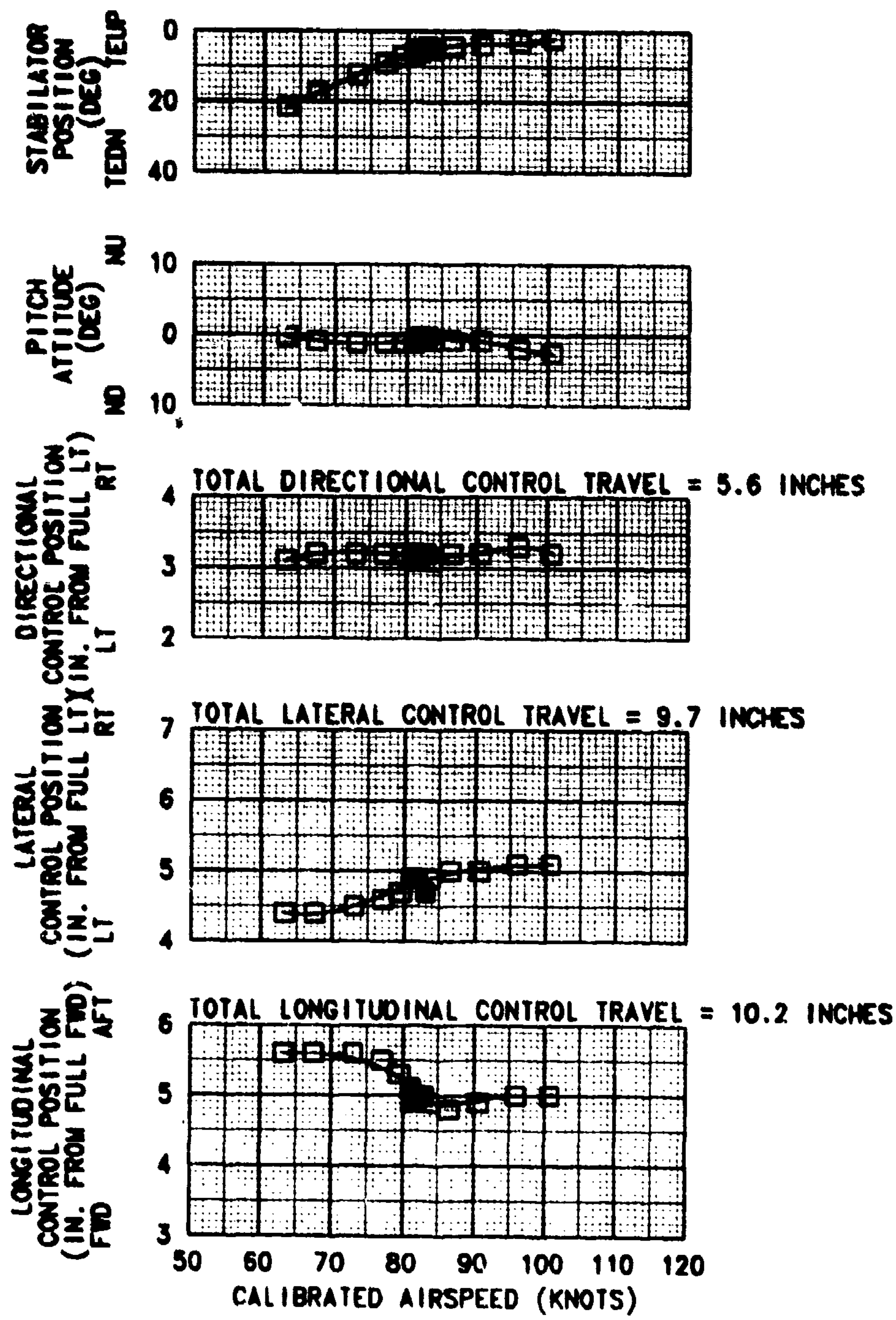


FIGURE 19
STATIC LATERAL-DIRECTIONAL STABILITY
UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
□	20790	351.7MID	0.3 LT	5300	18.0	258	82
⊙	20460	350.6MID	0.3 LT	5100	18.0	257	119

NOTE: 1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. PBA CENTERED AND LOCKED

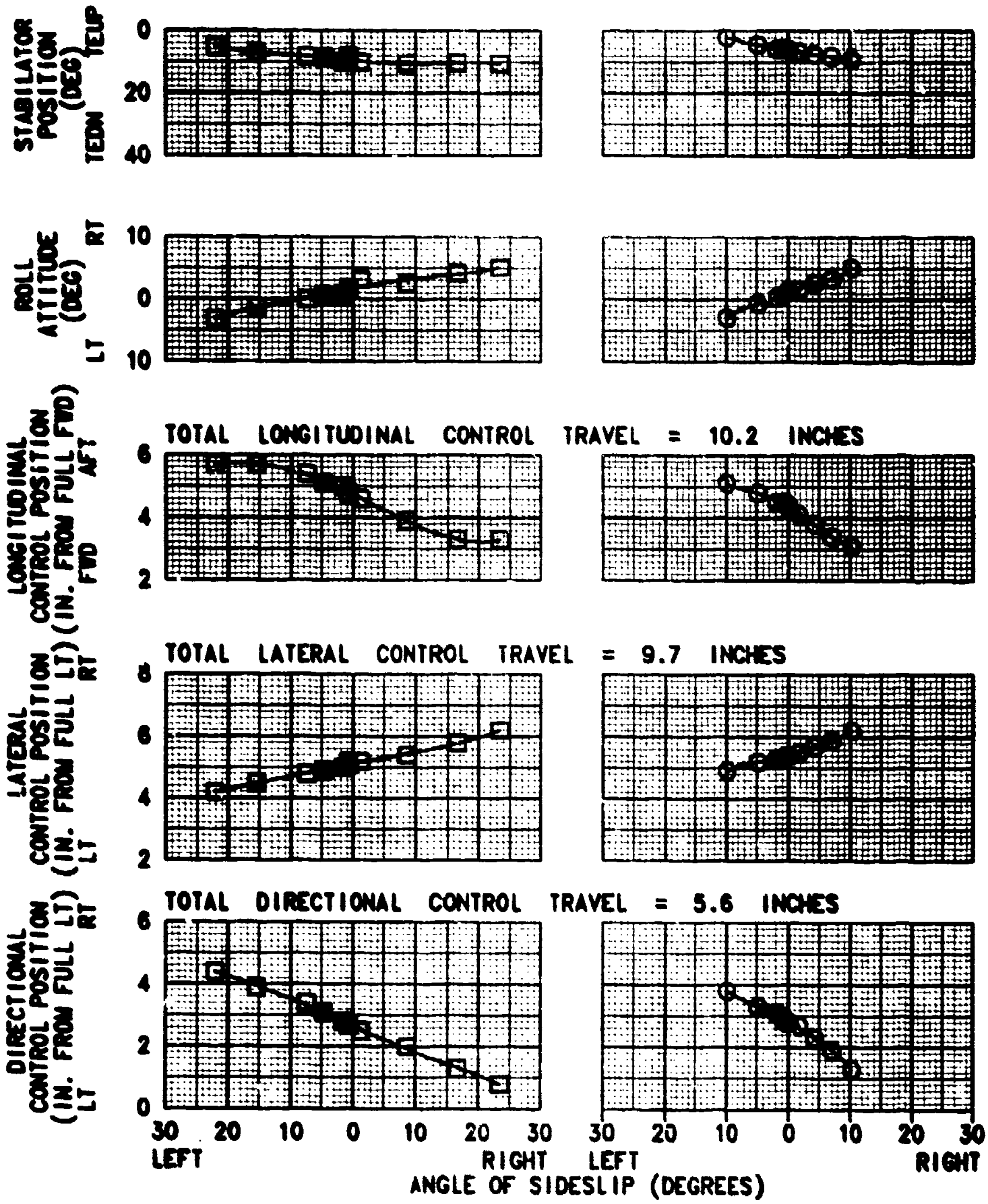


FIGURE 20
STATIC LATERAL-DIRECTIONAL STABILITY
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20710	351.4MID	0.3 LT	4880	16.5	258	83

NOTE:
1. VOLCANO CONFIGURATION
2. IRP CLIMB
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. PBA CENTERED AND LOCKED

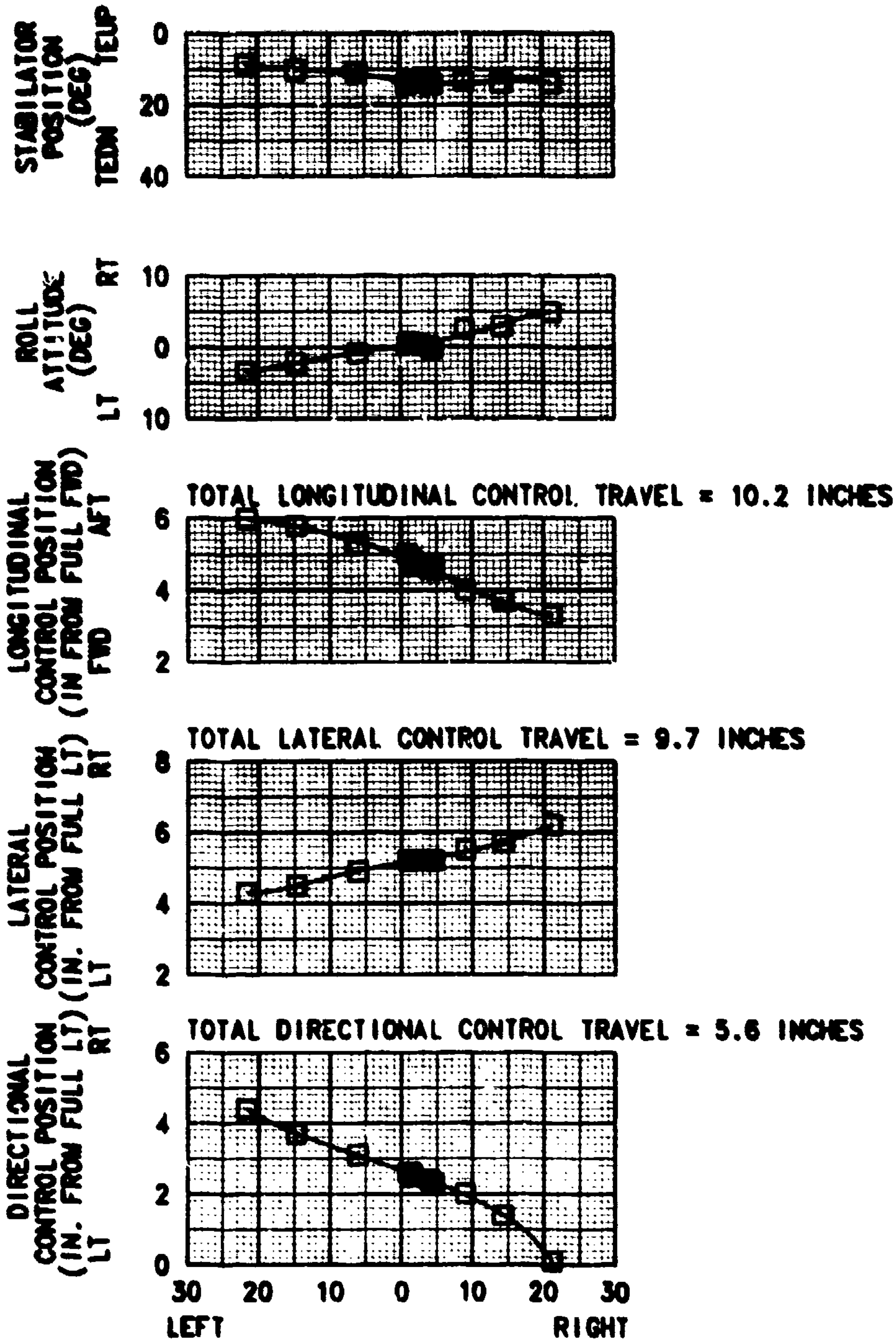


FIGURE 21
STATIC LATERAL-DIRECTIONAL STABILITY
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20850	351.3MID	0.3 LT	4890	16.0	258	83

NOTE: 1. VOLCANO CONFIGURATION
2. 1000 FT. PER MIN. DESCENT
3. SHADED SYMBOLS DENOTE TRIM POINTS
4. PBA CENTERED AND LOCKED

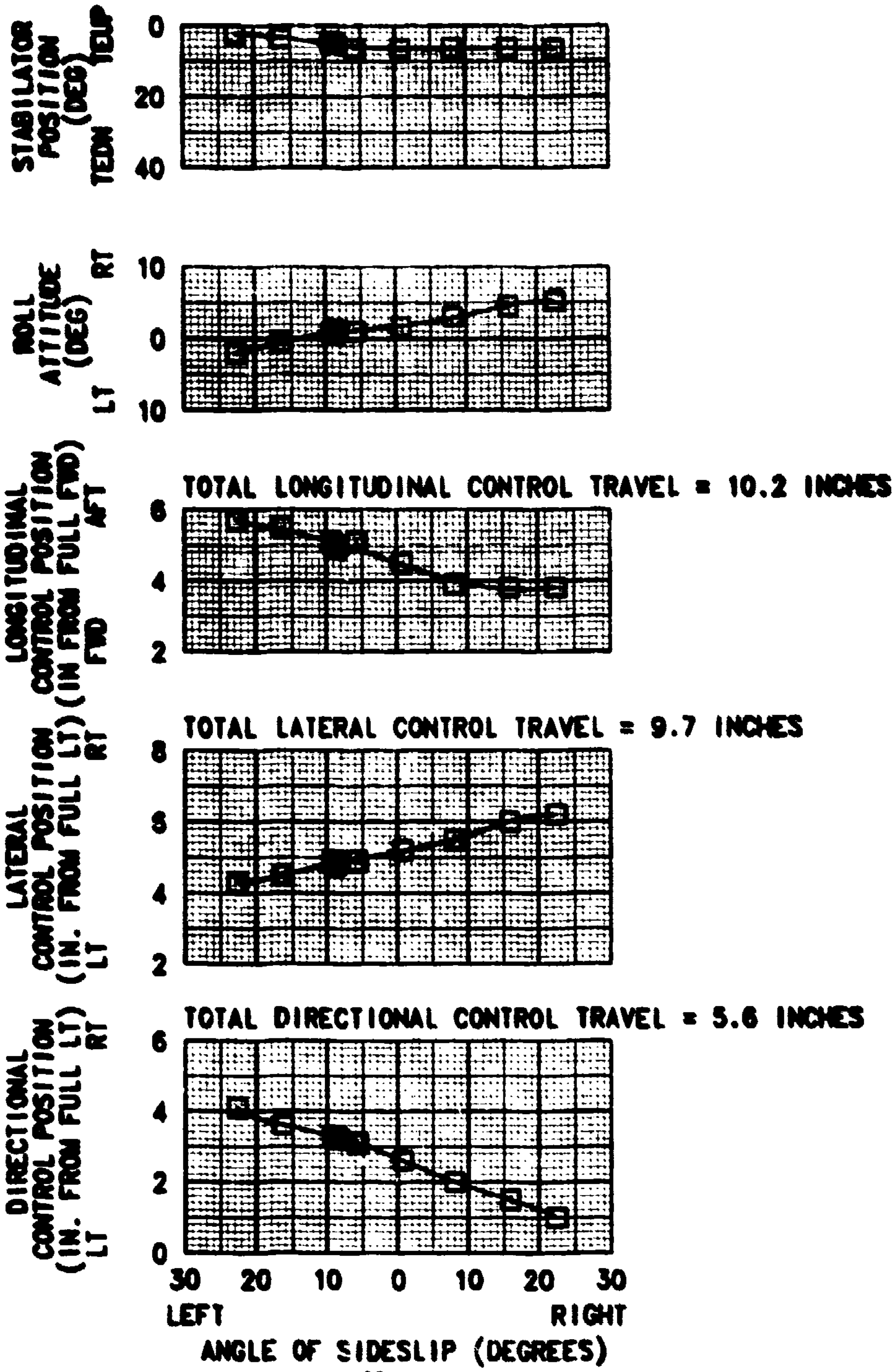


FIGURE 22
MANEUVERING STABILITY
SYMMETRICAL PUSHOVERS AND PULLUPS
UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
□	20590	349.7MID	0.3 LT	4990	13.5	259	40	ON
⊙	20400	349.0MID	0.3 LT	5290	13.5	259	40	OFF

NOTE: 1. VOLCANO CONFIGURATION
2. PBA CENTERED AND LOCKED

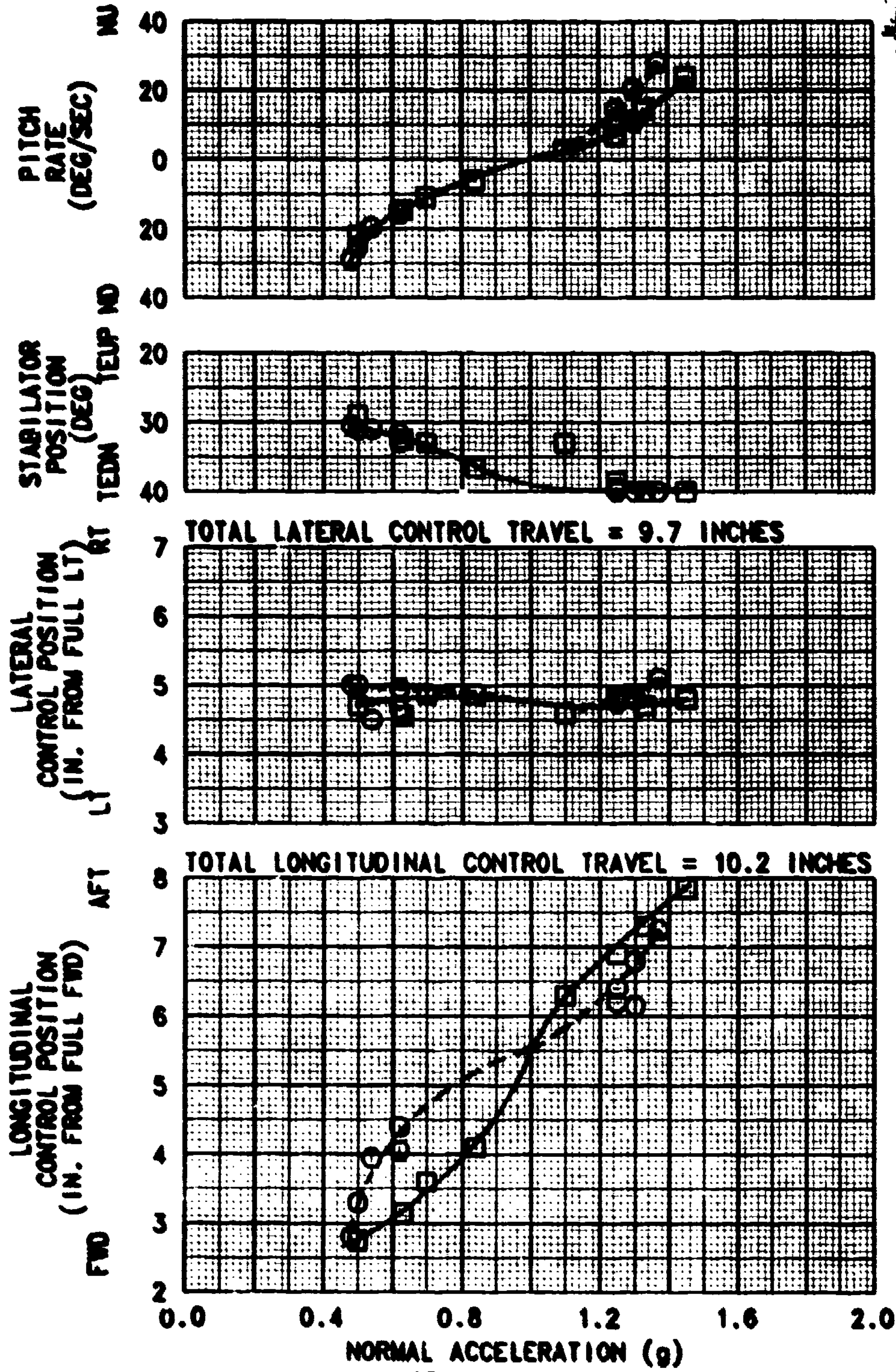


FIGURE 23
MANEUVERING STABILITY
SYMMETRICAL PUSHOVERS AND PULLUPS
UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
⊡	20990	351.0MID	0.3 LT	4950	13.5	259	100	ON
⊙	20780	350.3MID	0.3 LT	5000	14.5	259	100	OFF

NOTE: 1. VOLCANO CONFIGURATION
2. PBA CENTERED AND LOCKED

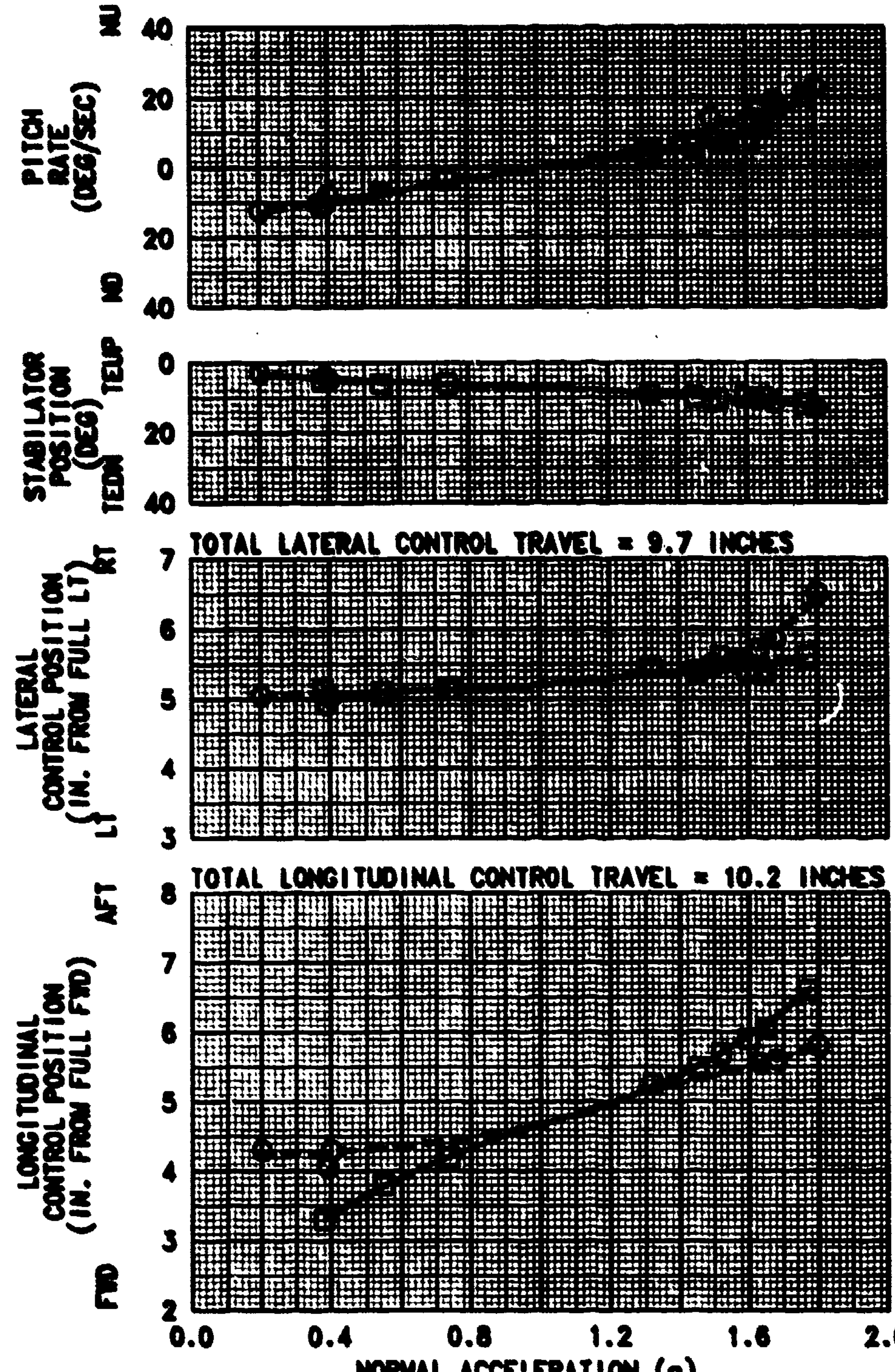


FIGURE 24
MANEUVERING STABILITY
UH-60A USA S/N 84-23953

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	TRIM FLIGHT CONDITION	SAS CONDITION
⊡	20970	350.9MID	0.3 LT	7650	11.5	258	40	RIGHT TURN	ON
⊙	20940	350.8MID	0.3 LT	7060	11.5	258	42	LEFT TURN	ON
△	20900	350.7MID	0.3 LT	6650	11.5	258	40	RIGHT TURN	OFF
◇	20850	350.5MID	0.3 LT	6400	12.0	258	41	LEFT TURN	OFF

NOTE: 1. VOLCANO CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM POINT
3. PBA CENTERED AND LOCKED

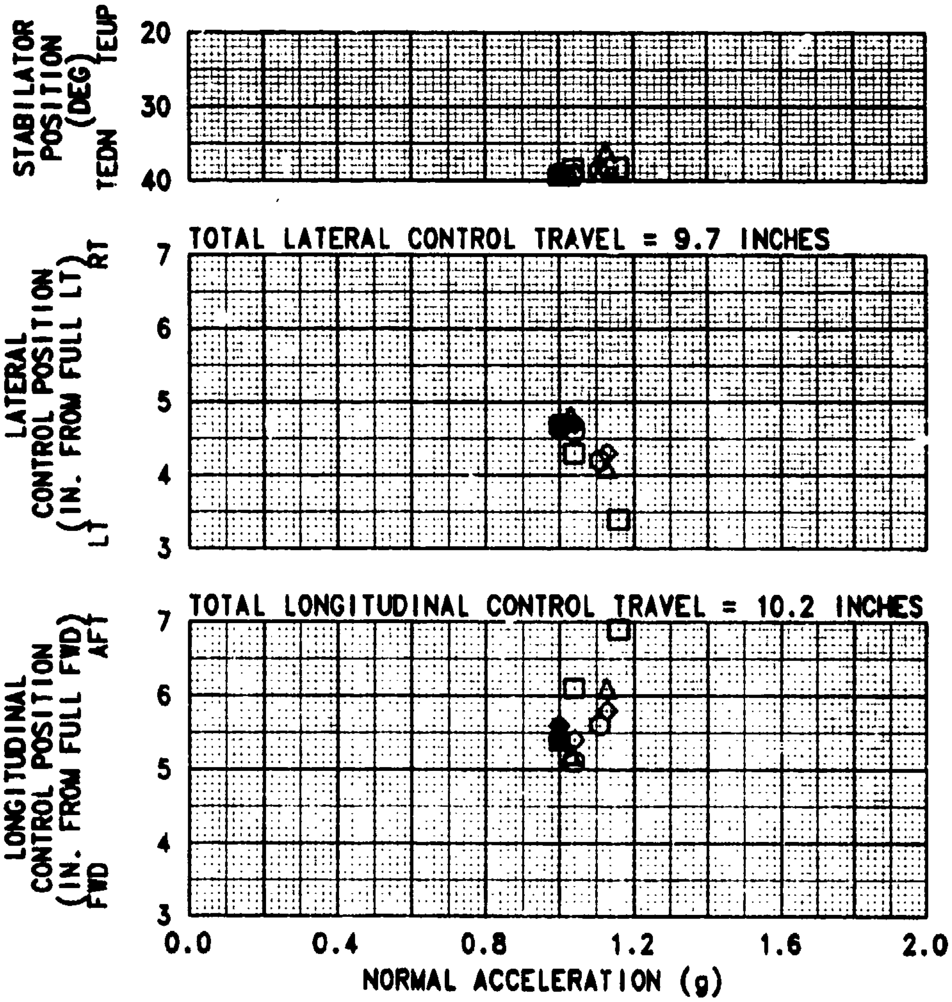


FIGURE 25
MANEUVERING STABILITY
UH-60A USA S/N 84-23953

SYM	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	TRIM FLIGHT CONDITION	SAS CONDITION
⊡	20910	350.7MID	0.3 LT	7180	11.0	259	101	RIGHT TURN	ON
⊙	20740	350.2MID	0.3 LT	7050	11.5	257	102	LEFT TURN	ON
△	20600	349.7MID	0.3 LT	7900	10.0	259	102	RIGHT TURN	OFF
◇	20480	349.3MID	0.3 LT	7930	10.5	258	103	LEFT TURN	OFF

NOTE: 1. VOLCANO CONFIGURATION
2. SHADED SYMBOLS DENOTE TRIM POINT
3. PBA CENTERED AND LOCKED

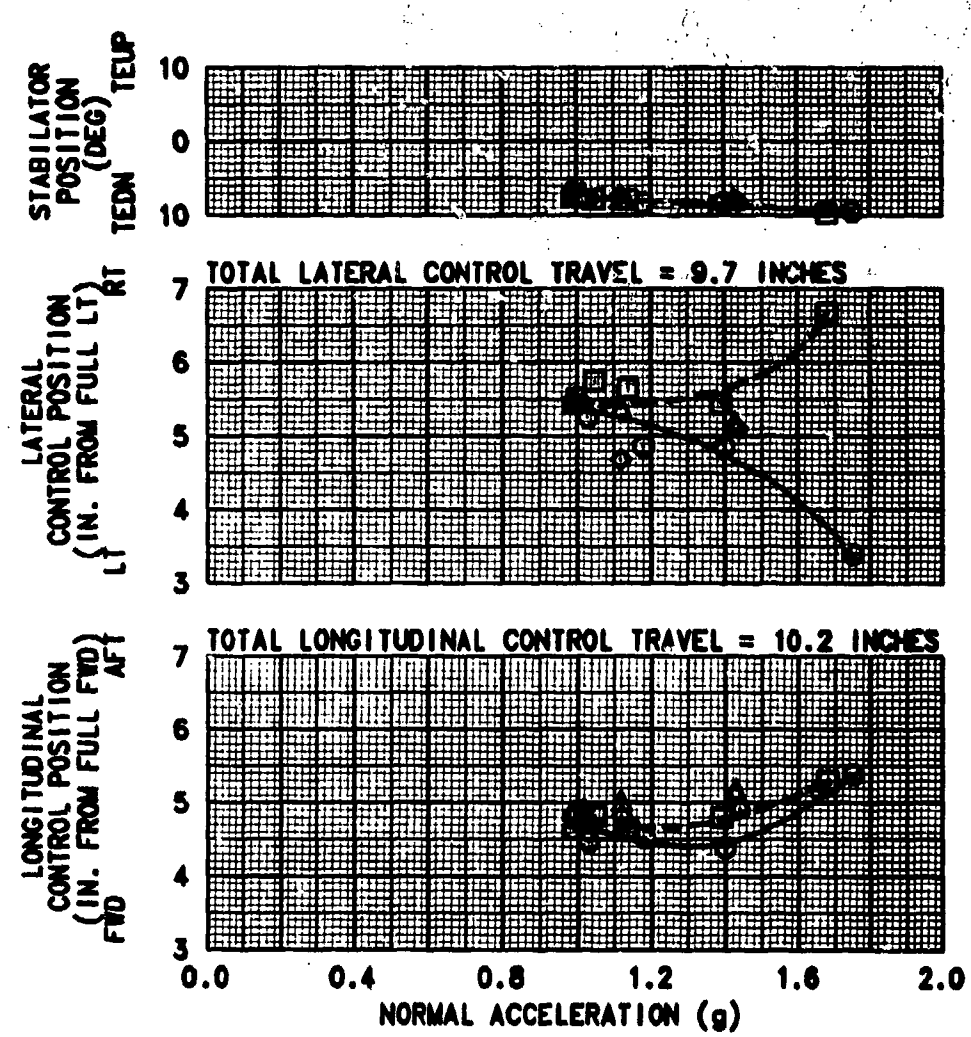


FIGURE 26
FORWARD LONGITUDINAL PULSE
UH-60A USA S/N 84-23883

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
20850	351.9 MID	0.3 LT	5100	13.5	258	82	ON

SHORT DASH　LONG DASH　SOLID LINE

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. PDA CENTERED AND LOCKED
3. LEVEL FLIGHT

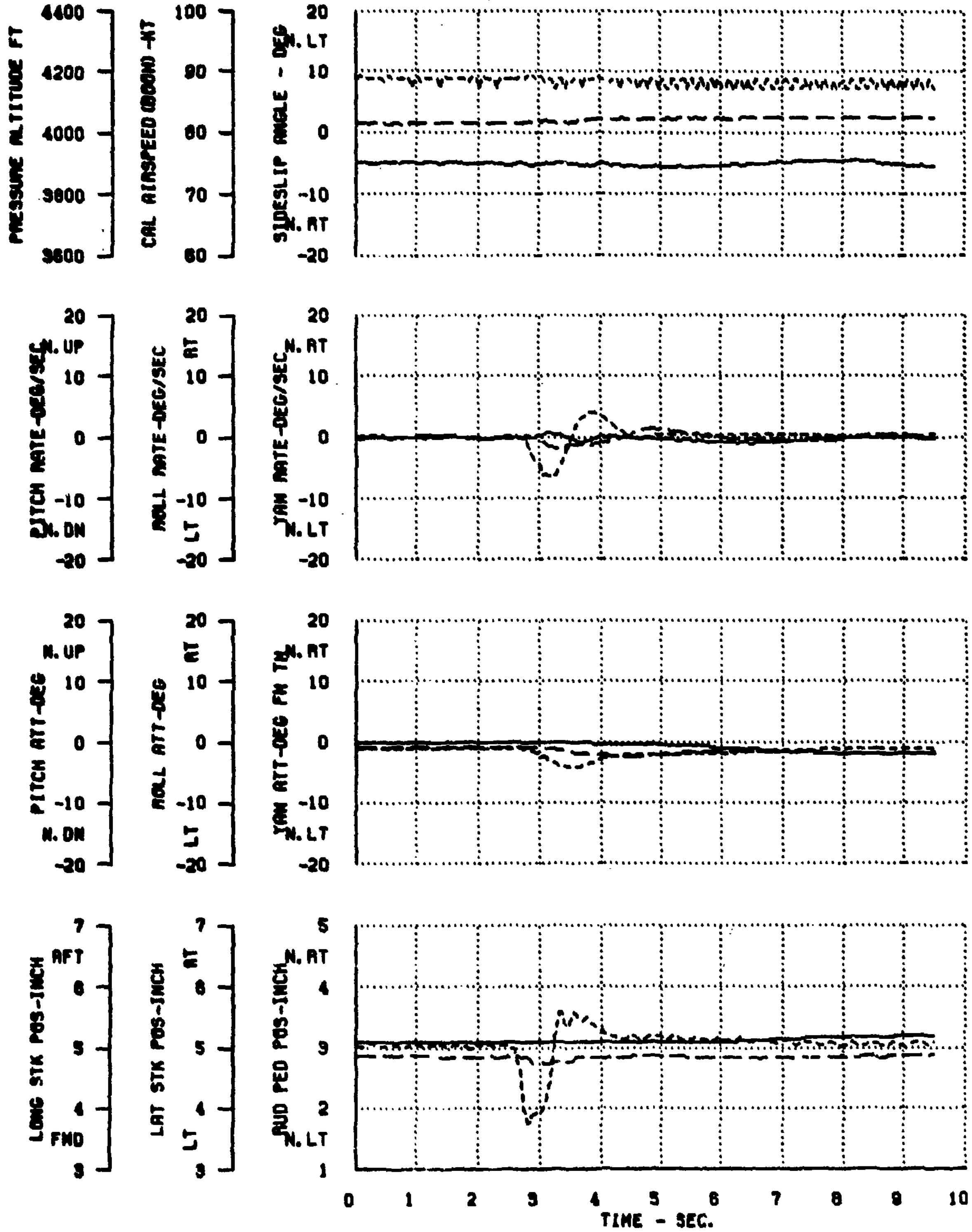


FIGURE 27
RIGHT LATERAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
20790	351.7 MID	0.3 LT	5240	14.5	258	82	ON

SHORT DASH | LONG DASH | SOLID LINE

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. PBA CENTERED AND LOCKED
3. LEVEL FLIGHT

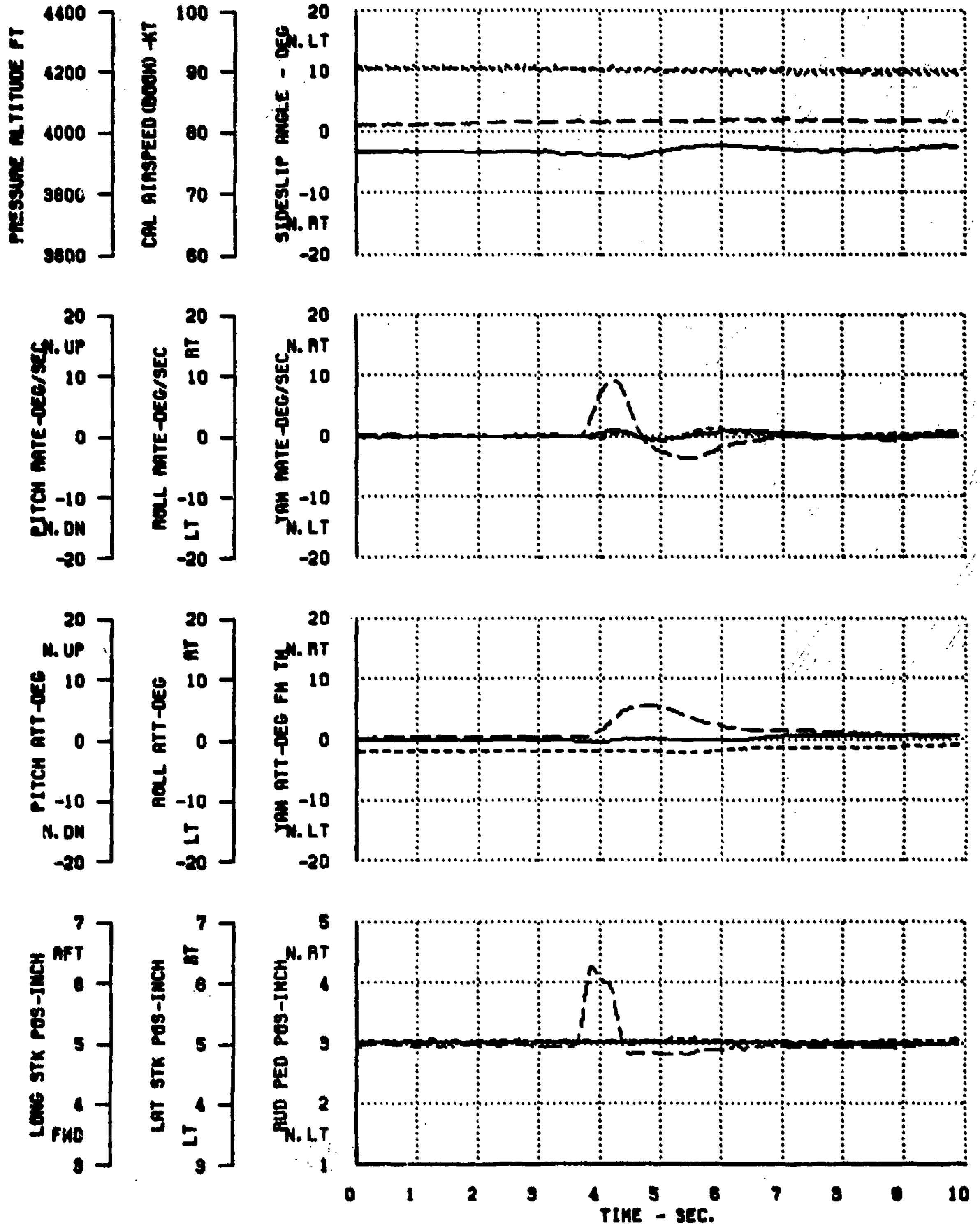


FIGURE 28
RIGHT DIRECTIONAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION
20650	351.3 MID	0.3 LT	5100	13.0	258	82	ON

SHORT DASH | LONG DASH | SOLID LINE

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. PBA CENTERED AND LOCKED
3. LEVEL FLIGHT

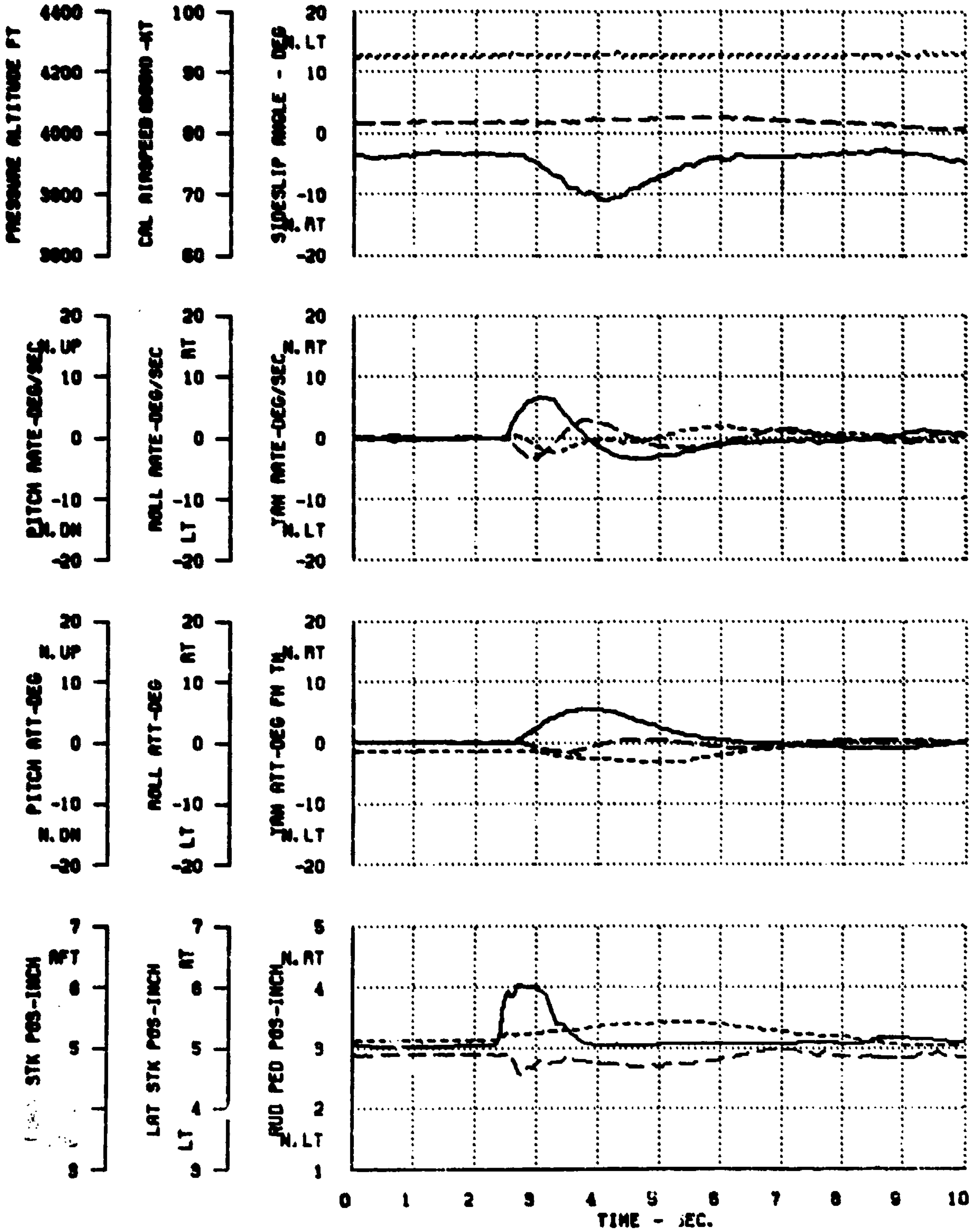


FIGURE 29
FORWARD LONGITUDINAL PULSE
UH-60A USA S/N 84-23963

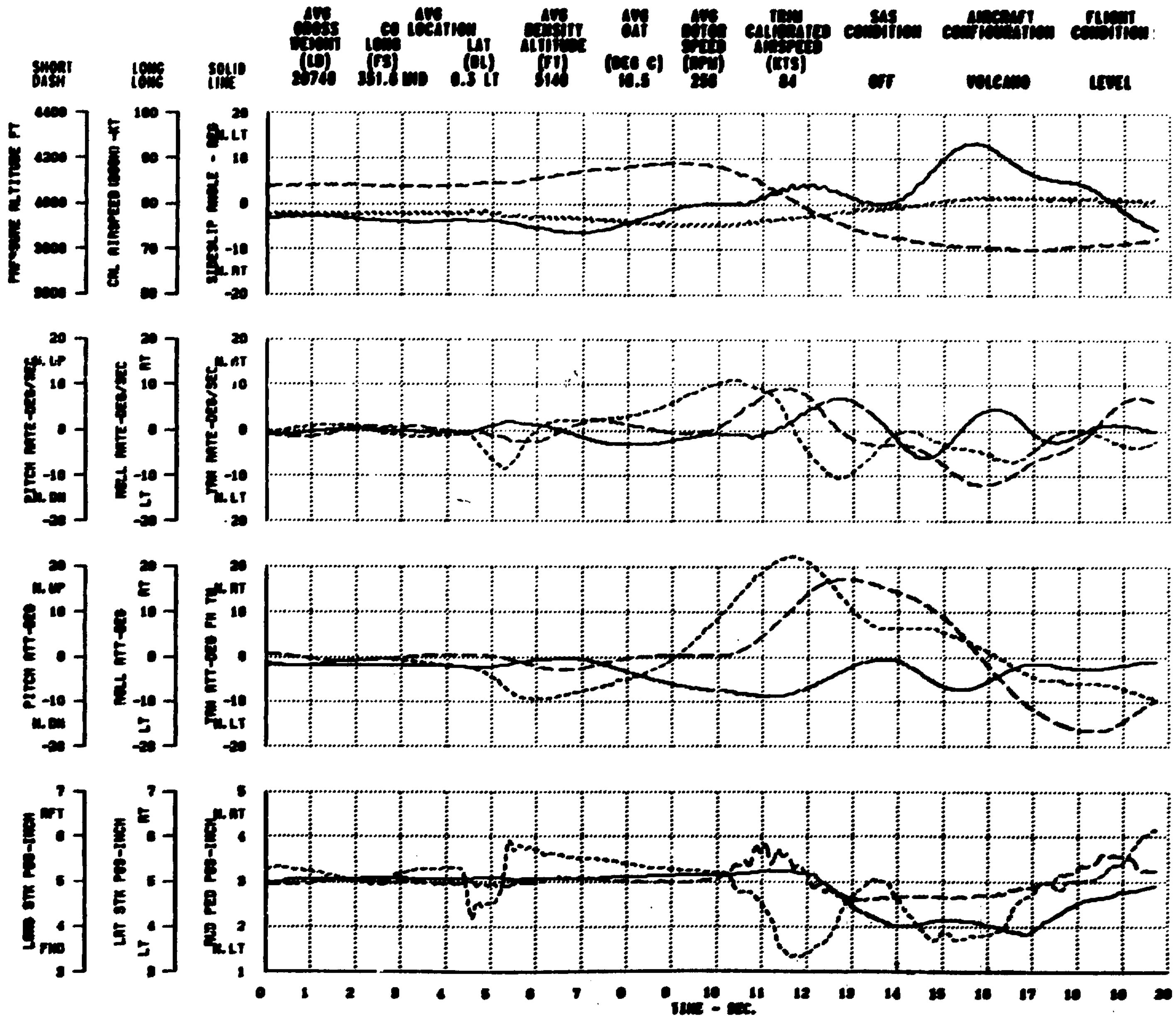


FIGURE 30
AFT LONGITUDINAL PULSE
UH-60A USA S/N 84-23965

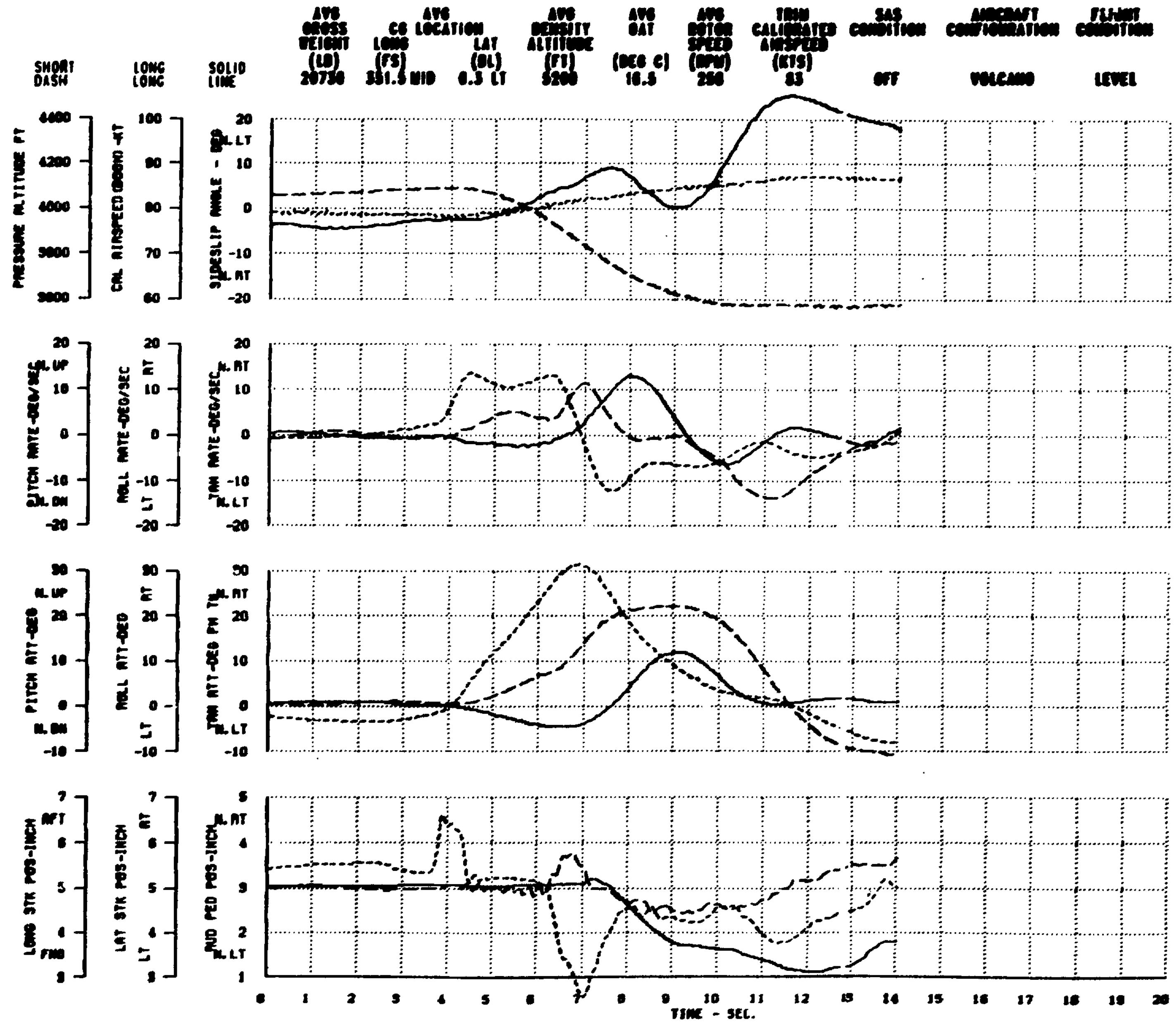


FIGURE 31
LEFT LATERAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20676	351.3 MID	0.3 LT	5240	16.5	258	84	OFF	VOLCANO	LEVEL

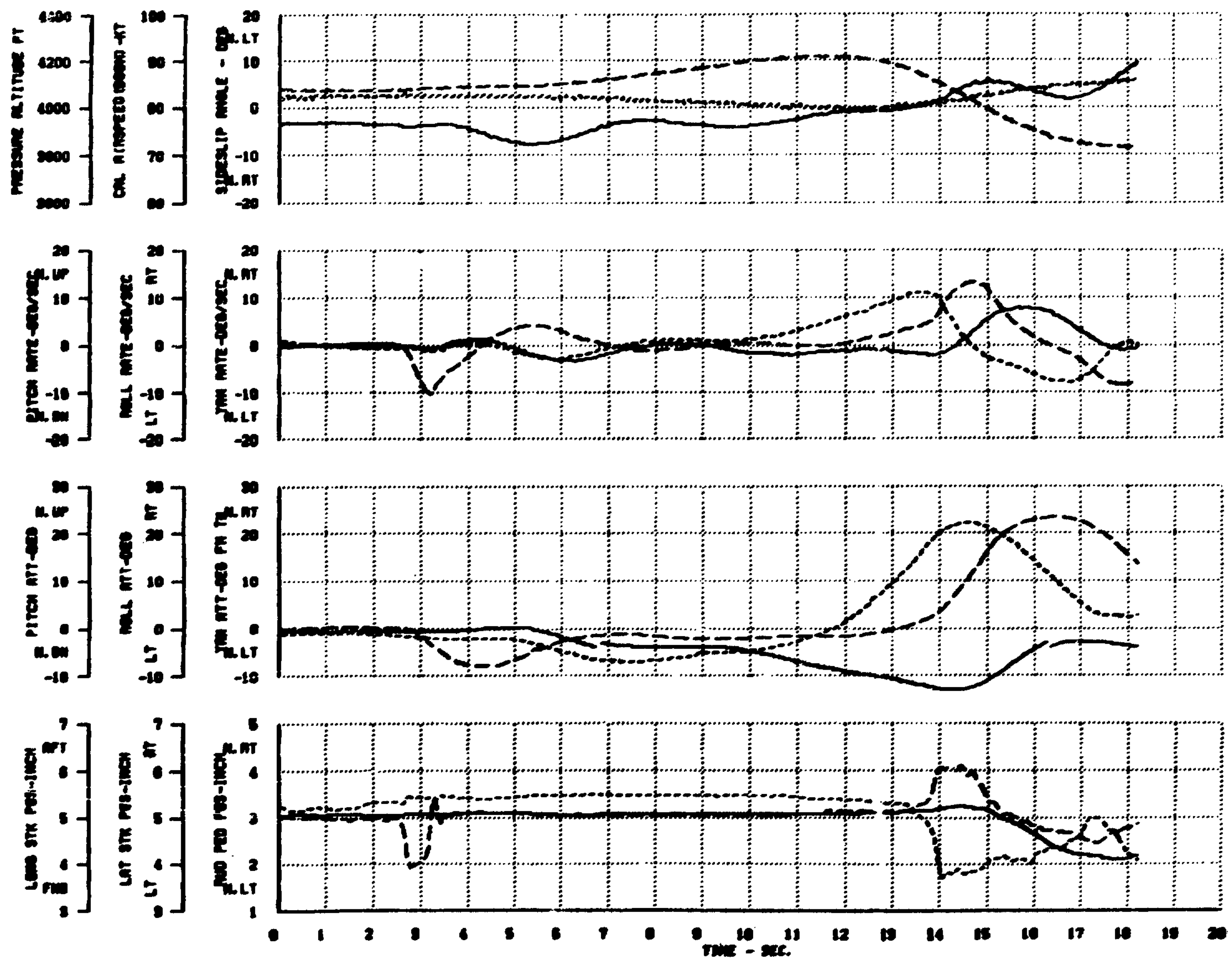


FIGURE 32
RIGHT LATERAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20720	351.4 MID	0.3 LT	5160	16.5	258	84	OFF	VOLCANO	LEVEL

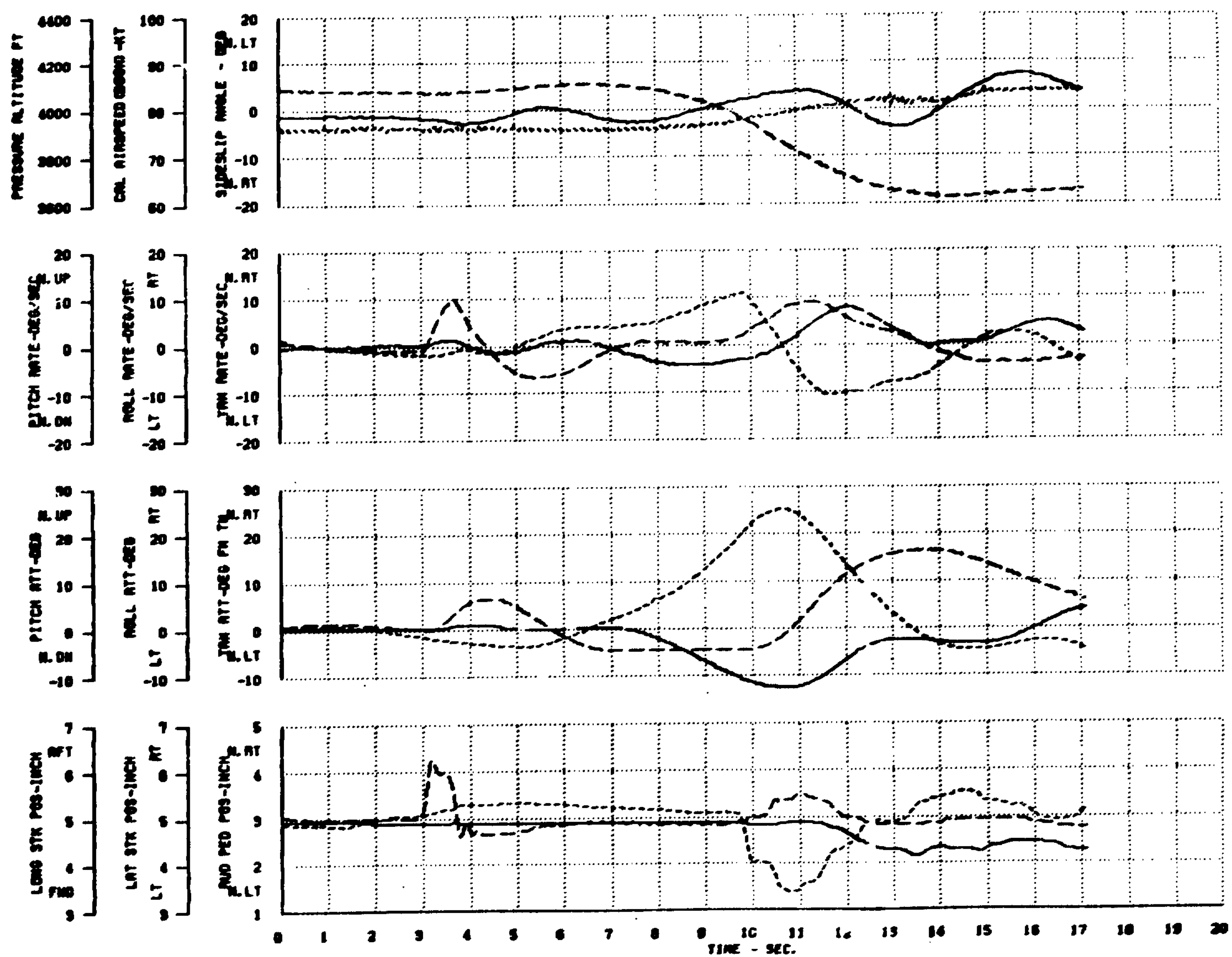


FIGURE 33
LEFT DIRECTIONAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20640	351.2 MID	0.3 LT	5200	16.0	258	84	OFF	VOLCANO	LEVEL

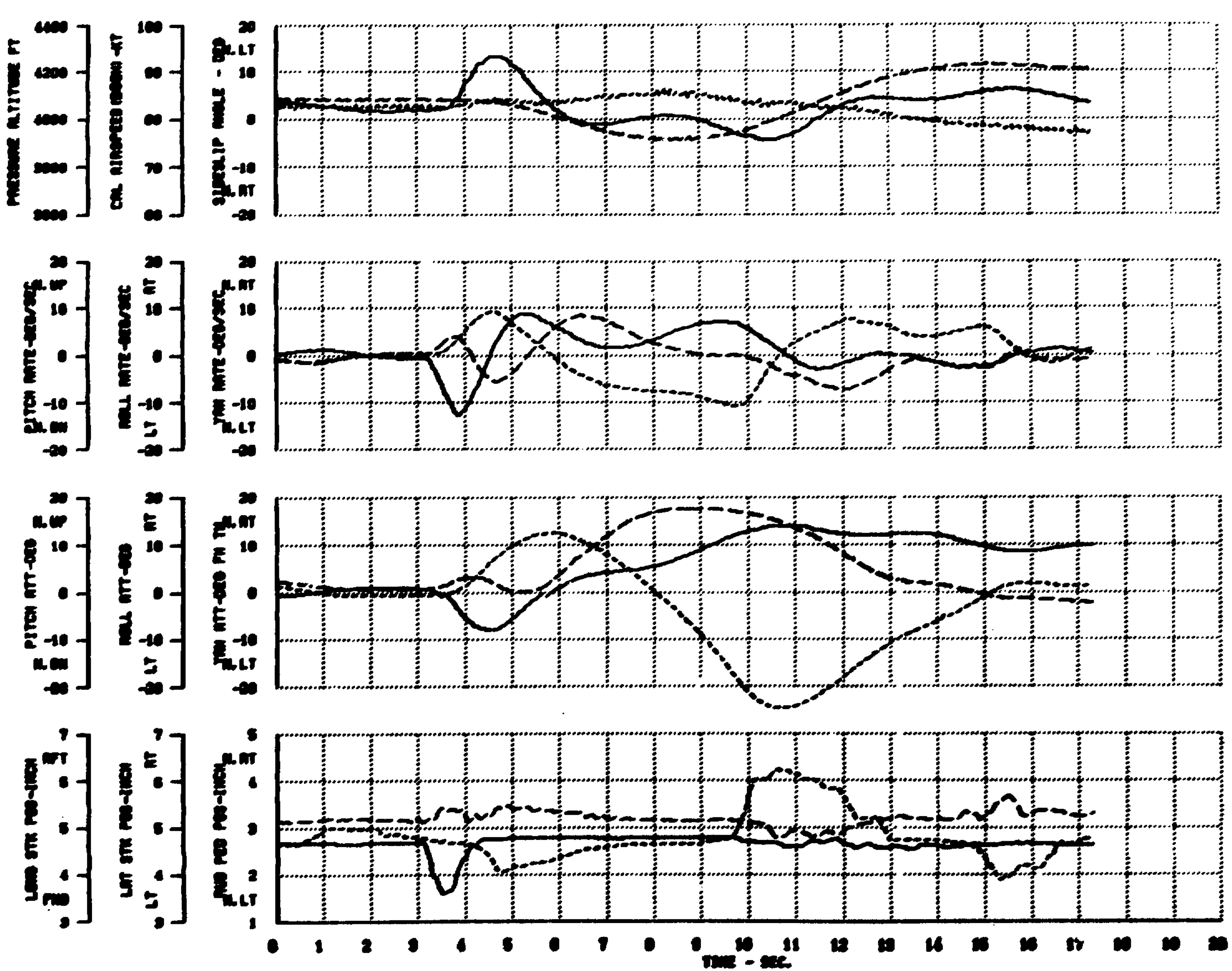


FIGURE 34

RIGHT DIRECTIONAL PULSE

UH-60A USA S/N 84-23303

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20640	351.2 MID	0.3 LT	5220	16.0	258	86	OFF	VOLCANO	LEVEL

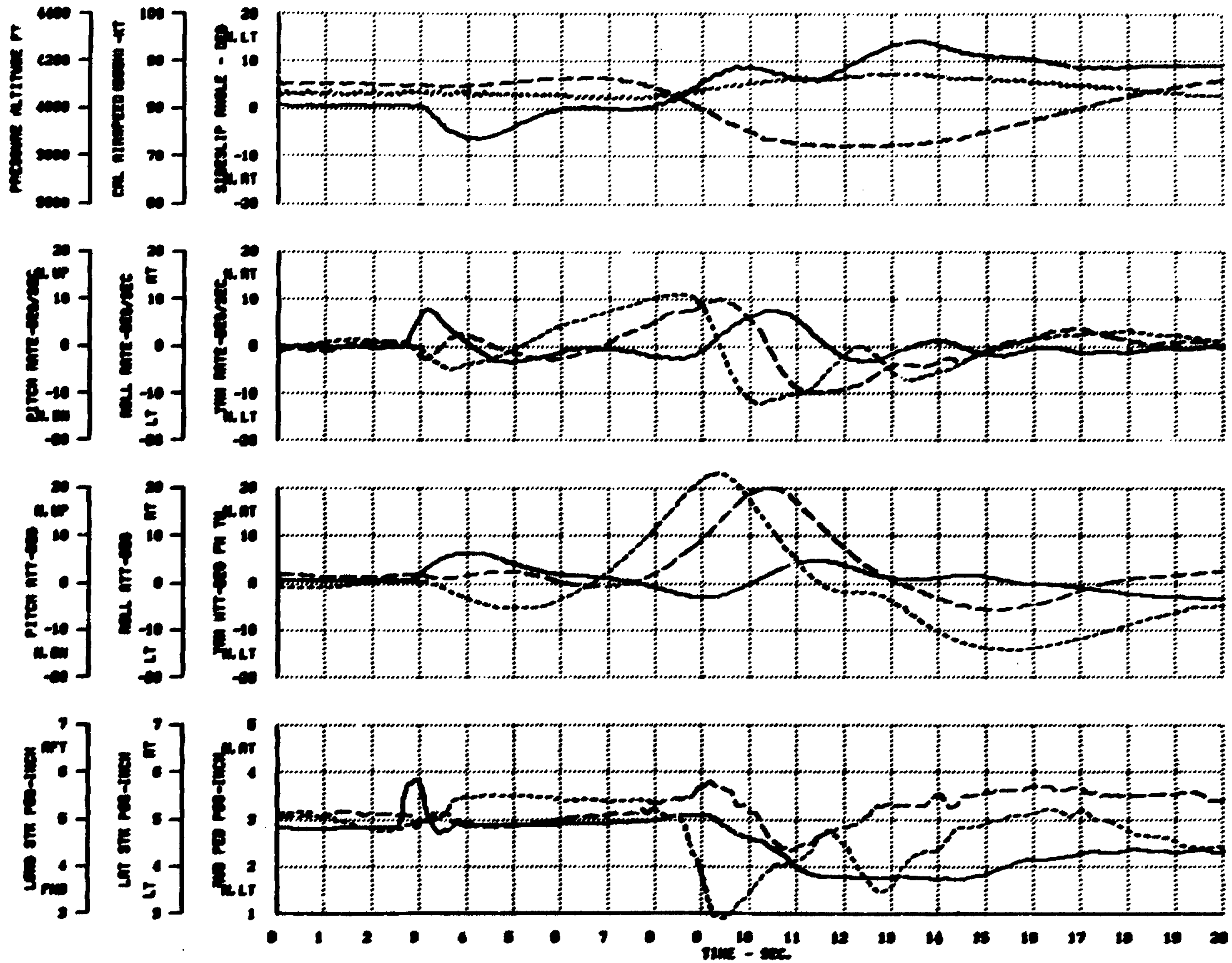


FIGURE 35
AFT LONGITUDINAL PULSE
UH-60A USA S/N 84-23963

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20540	349.0MID	0.3 LT	3200	13.0	258	83	OFF	VOLCANO	CLIMB

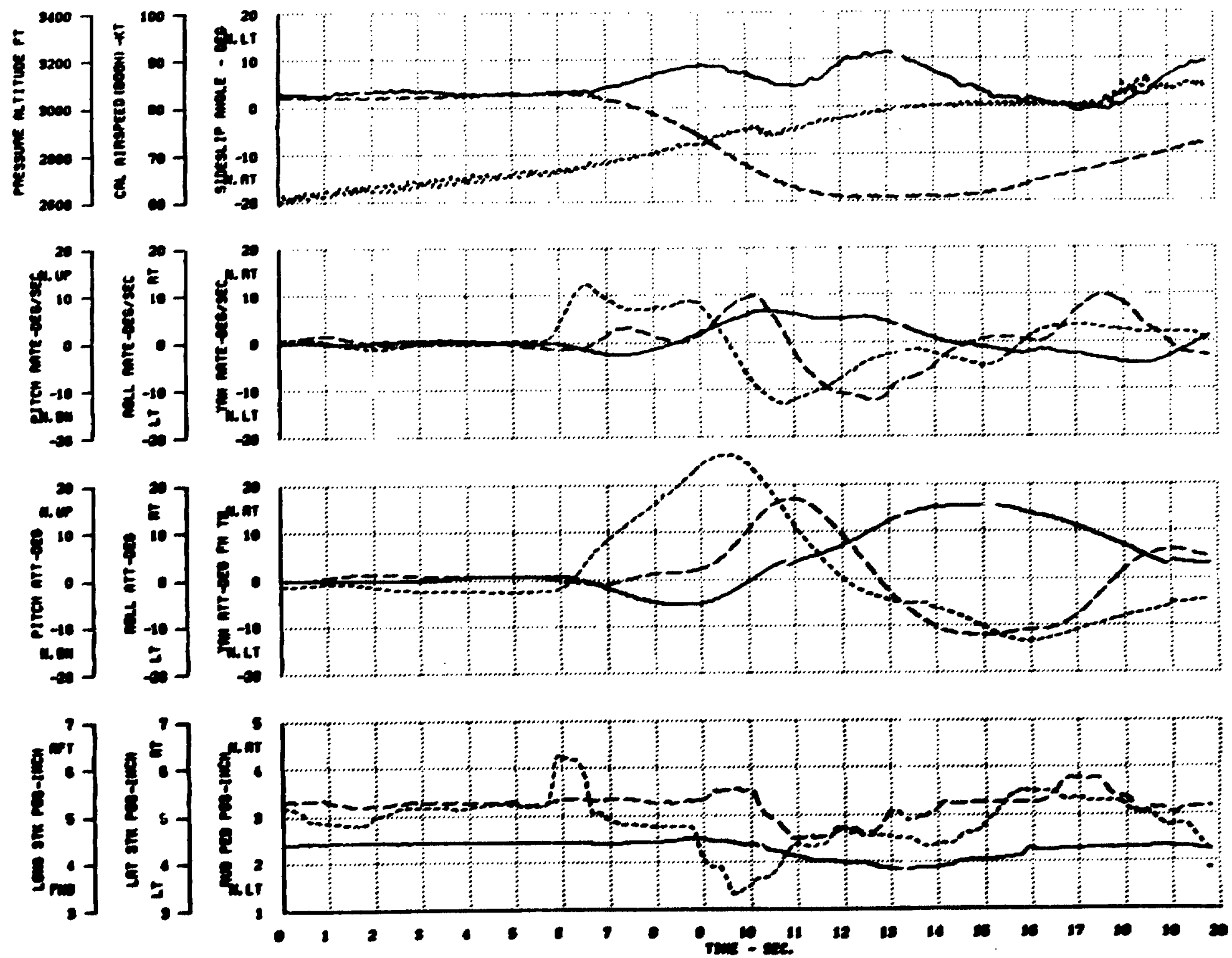


FIGURE 36
AFT LONGITUDINAL PULSE
UH-60A USA S/N 84-23953

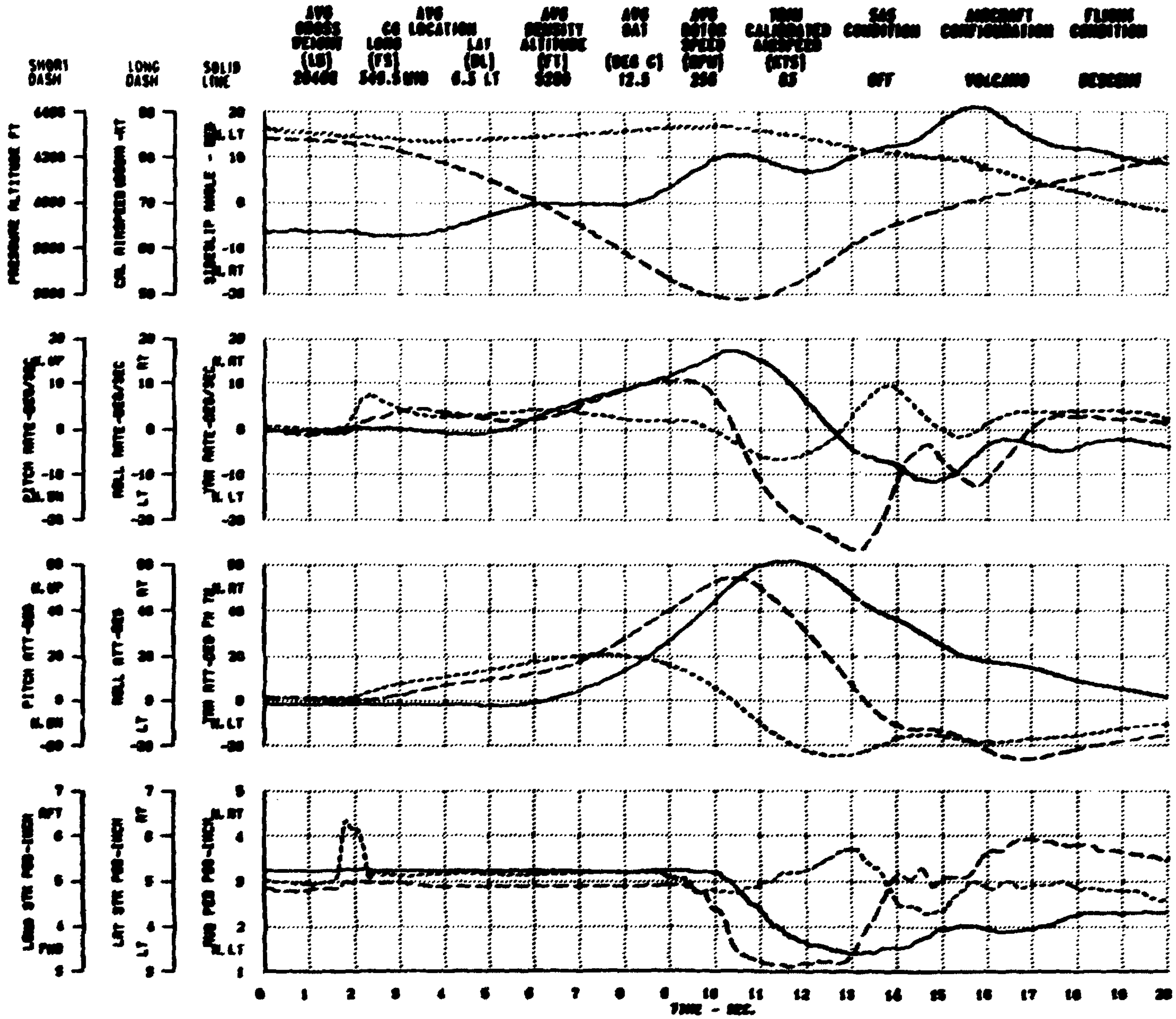


FIGURE 37
RIGHT LATERAL PULSE
UH-60A USA S/N 84-23983

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20520	349.8(MID)	0.3 LT	4320	12.0	258	86	OFF	VOLCANO	CLIMB

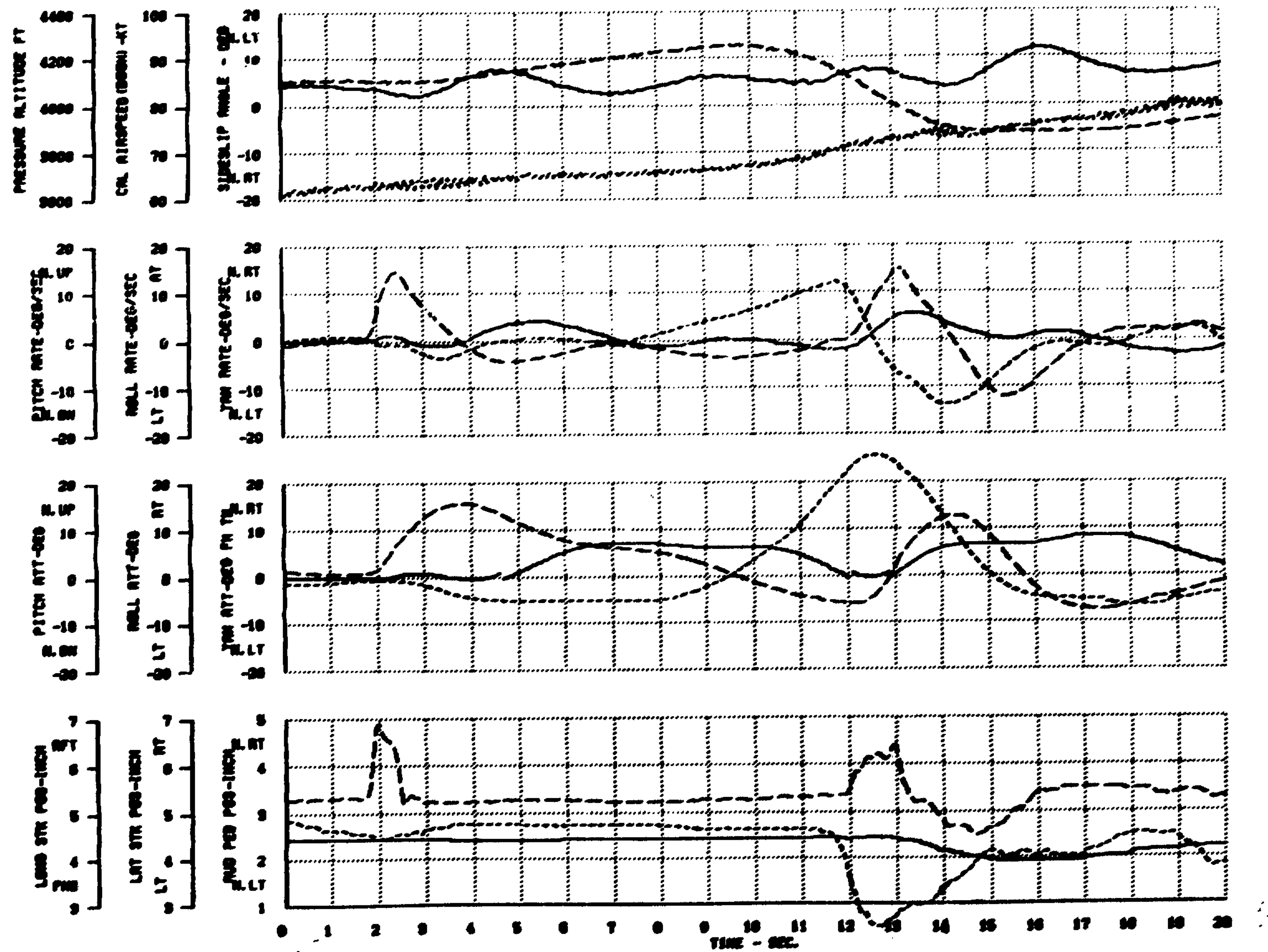


FIGURE 58
RIGHT LATERAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20400	349.4 MID	0.3 LT	2520	14.5	258	80	OFF	VOLCANO	DESCENT

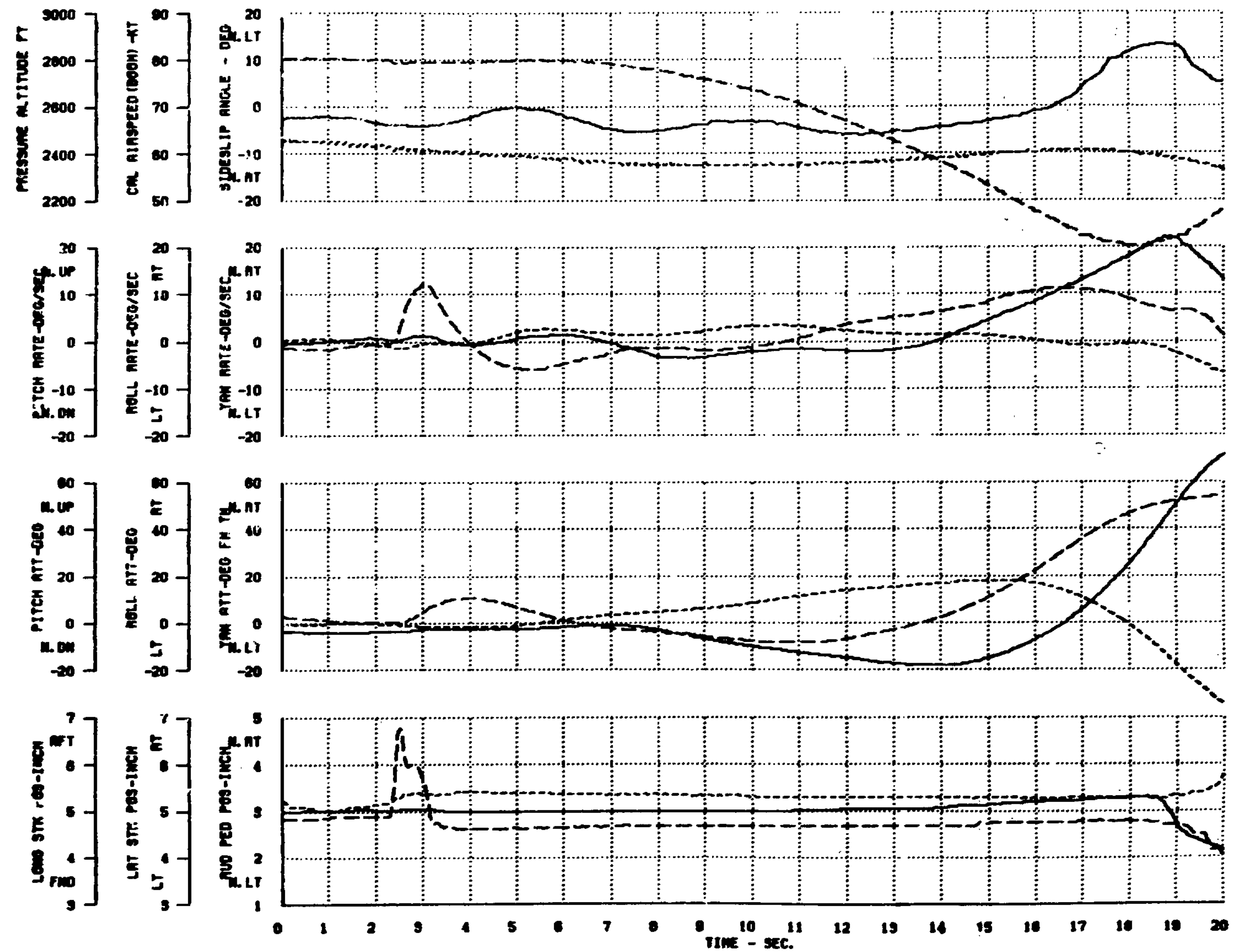


FIGURE 30
RIGHT DIRECTIONAL PULSE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20480	349.0MID	0.3 LT	6000	13.5	258	85	OFF	VOLCANO	CLIMB

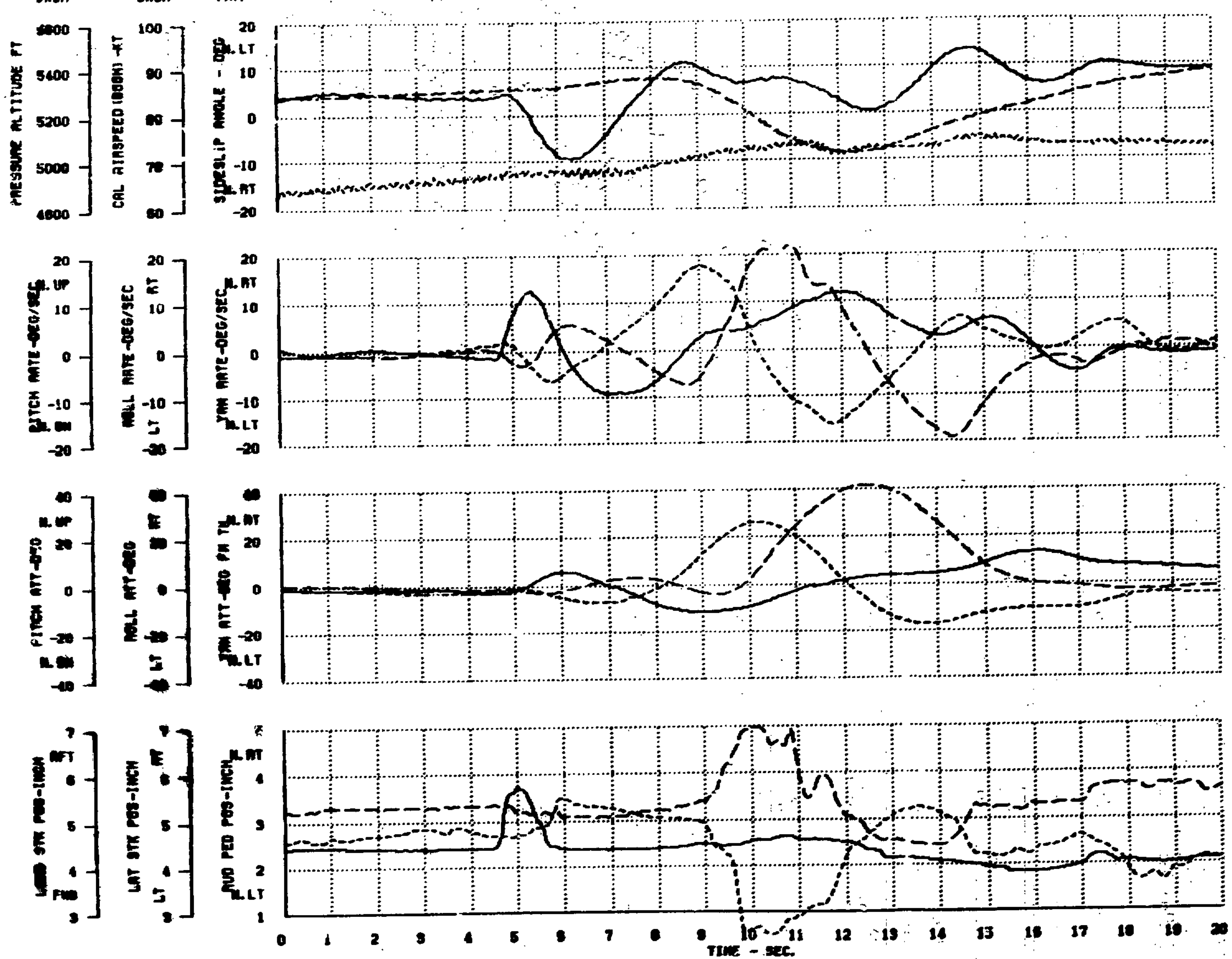


FIGURE 40

LONGITUDINAL CONTROLLABILITY

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20580	351.8MID	0.3 LT	-180	15.0	259	000

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

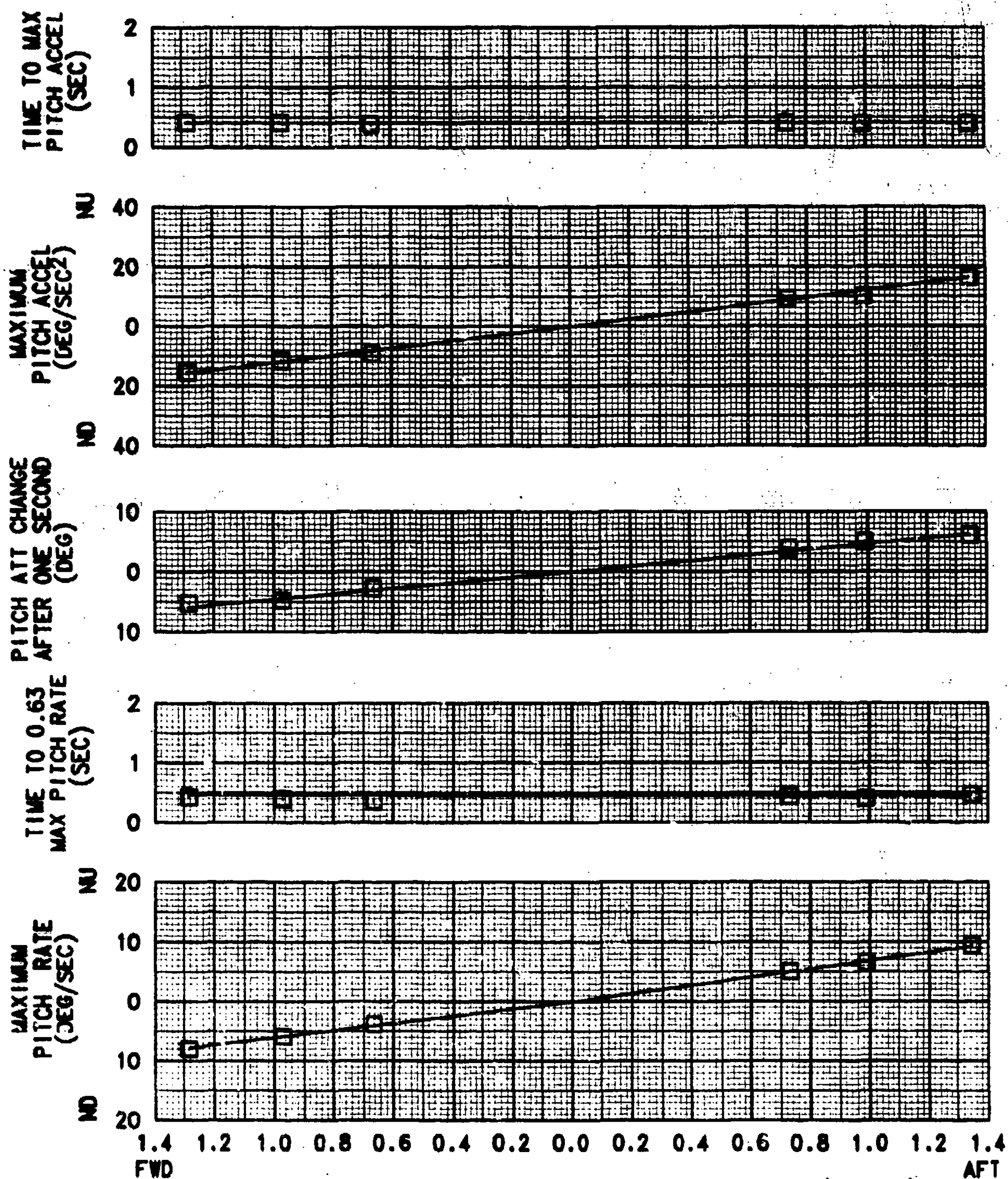


FIGURE 41
FORWARD LONGITUDINAL STEP
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20500	350.6MID	0.3 LT	-200	15.0	258	000

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

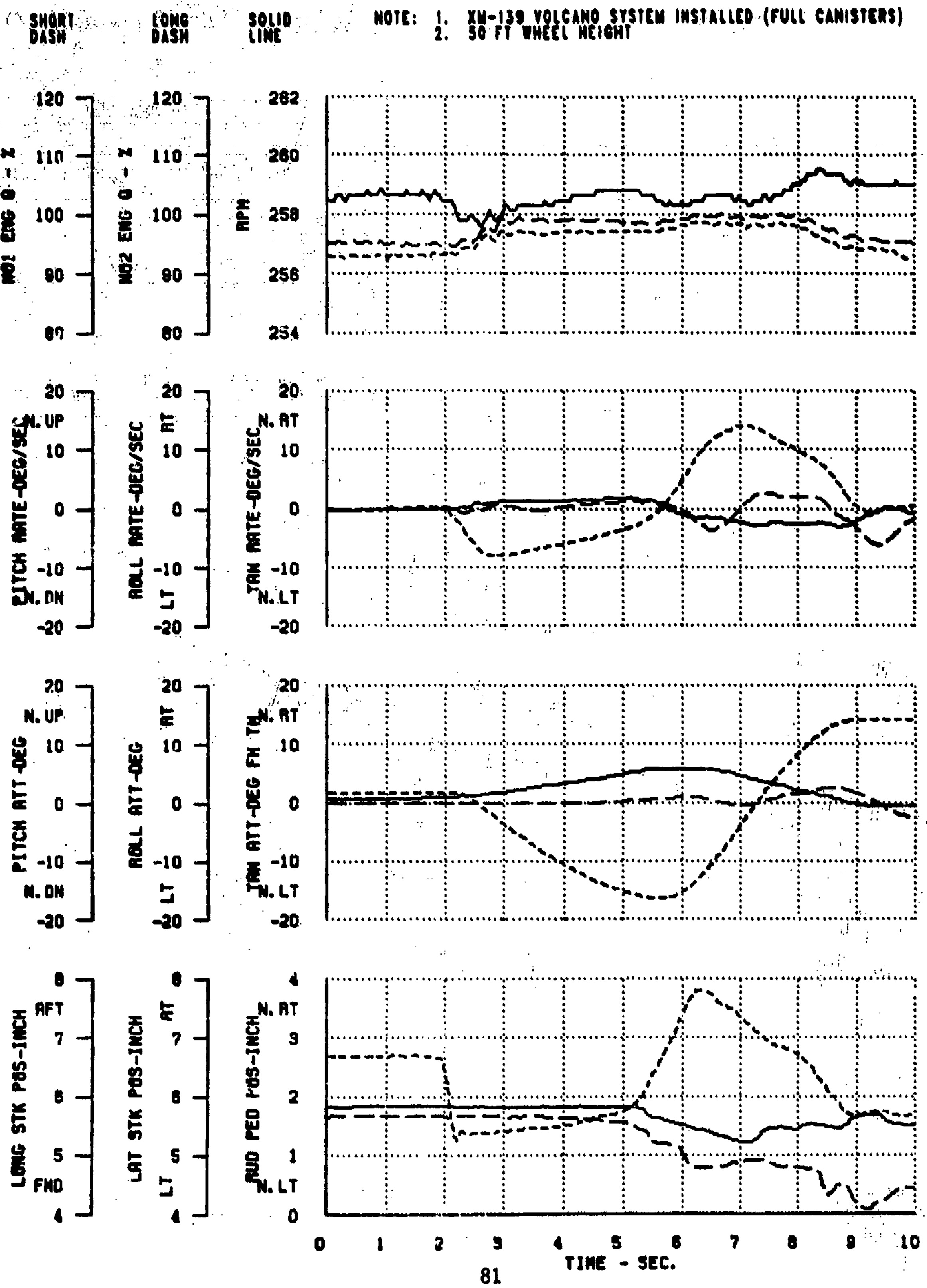


FIGURE 42
AFT LONGITUDINAL STEP
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20540	350.8 MID	0.3 LT	-160	15.3	259	000

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

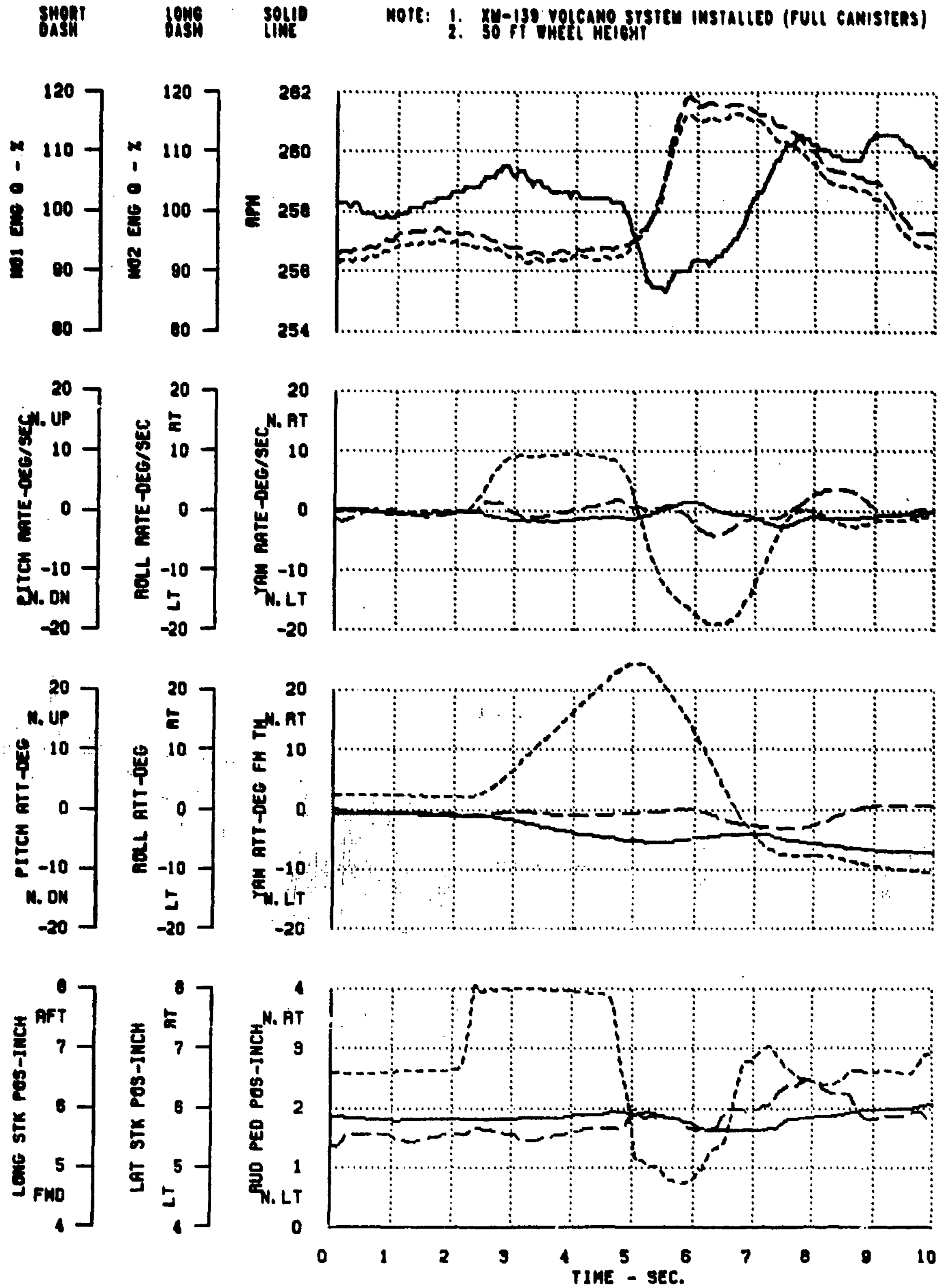


FIGURE 43
LATERAL CONTROLLABILITY
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20390	350.5MID	0.3 LT	-150	15.5	259	000

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

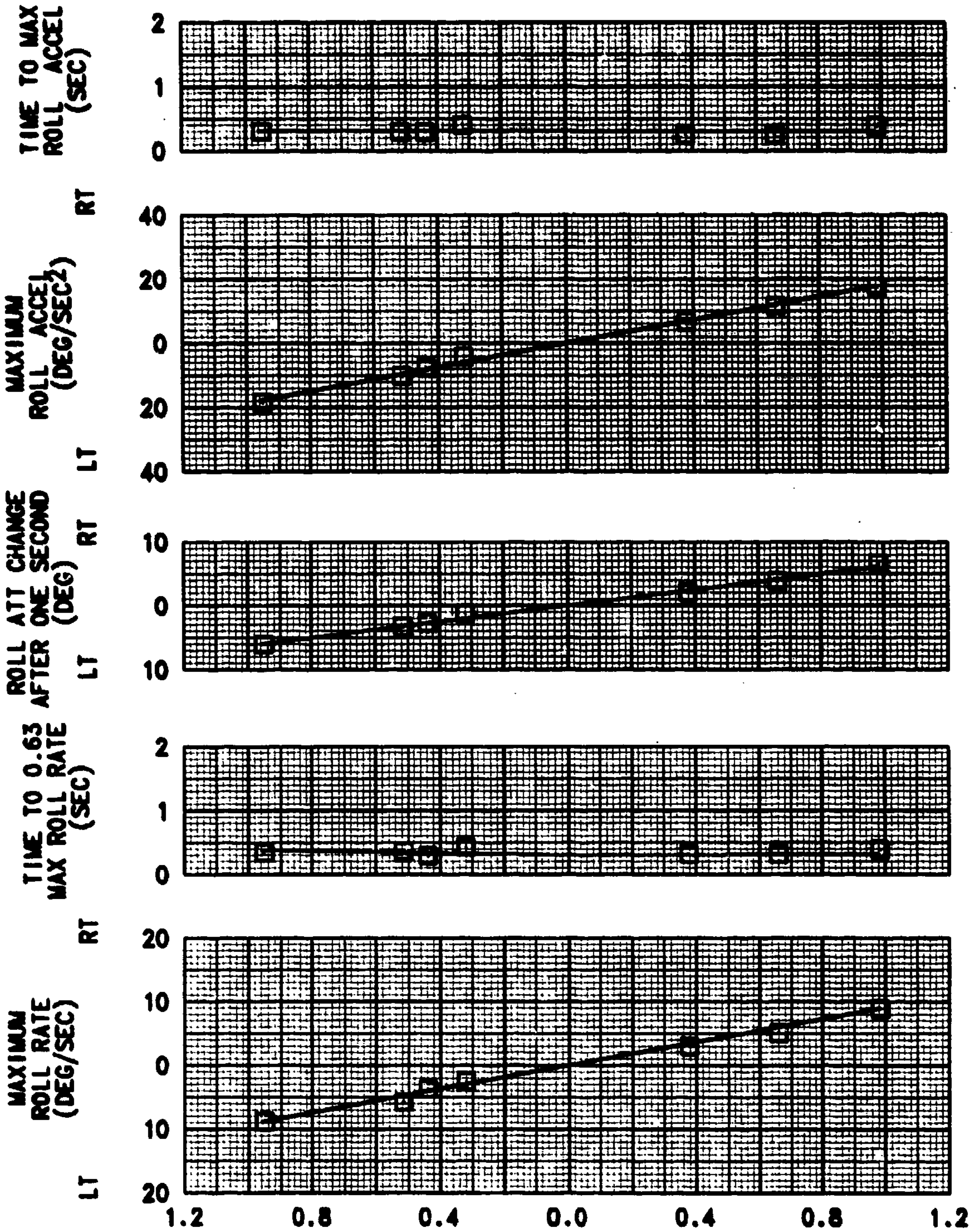


FIGURE 44
LEFT LATERAL STEP
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20340	350.1 MID	0.3 LT	-140	15.3	258	000

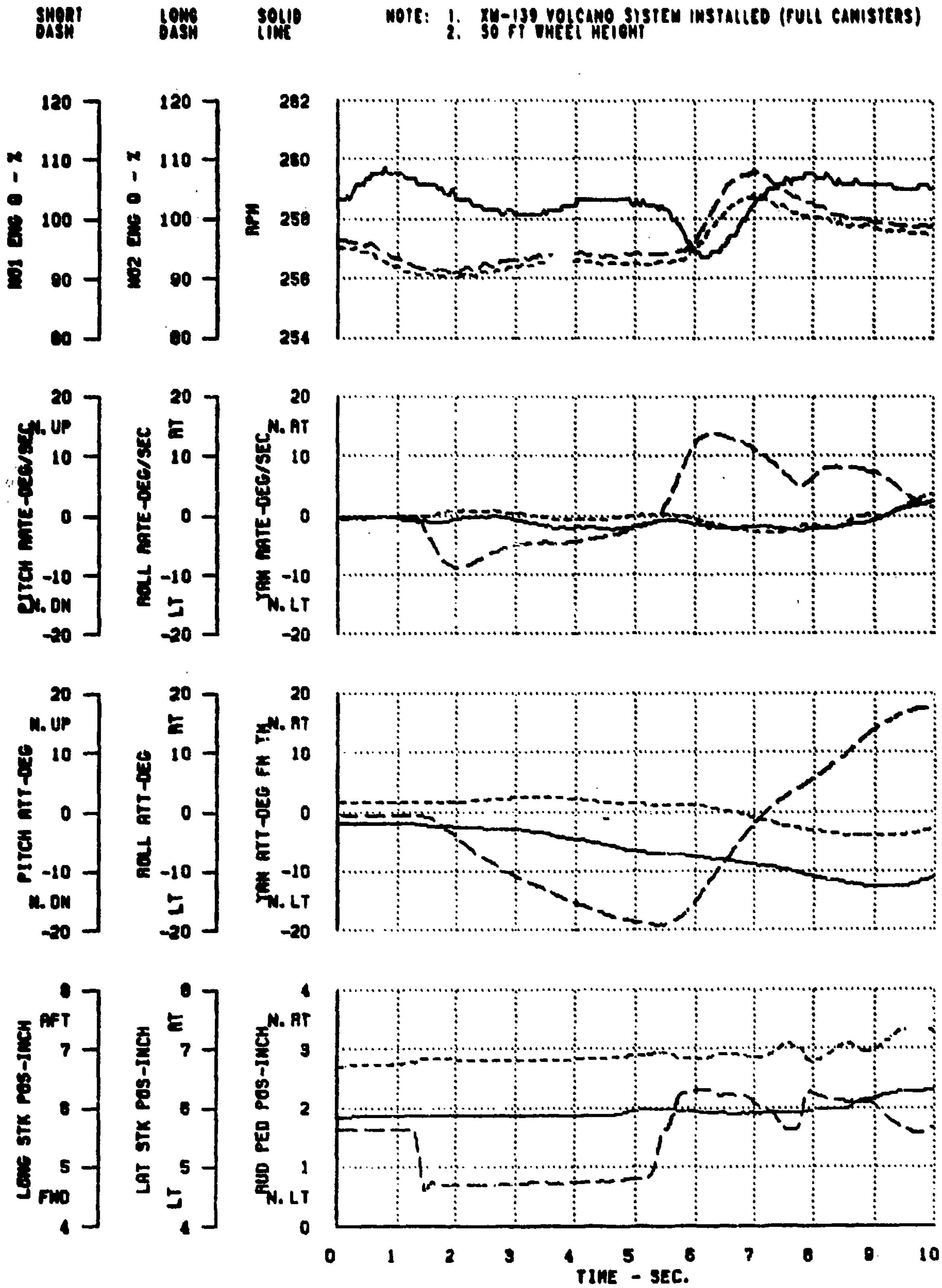


FIGURE 48

RIGHT LATERAL STEP

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20340	350.1 MID	0.3 LT	-140	15.3	258	000

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

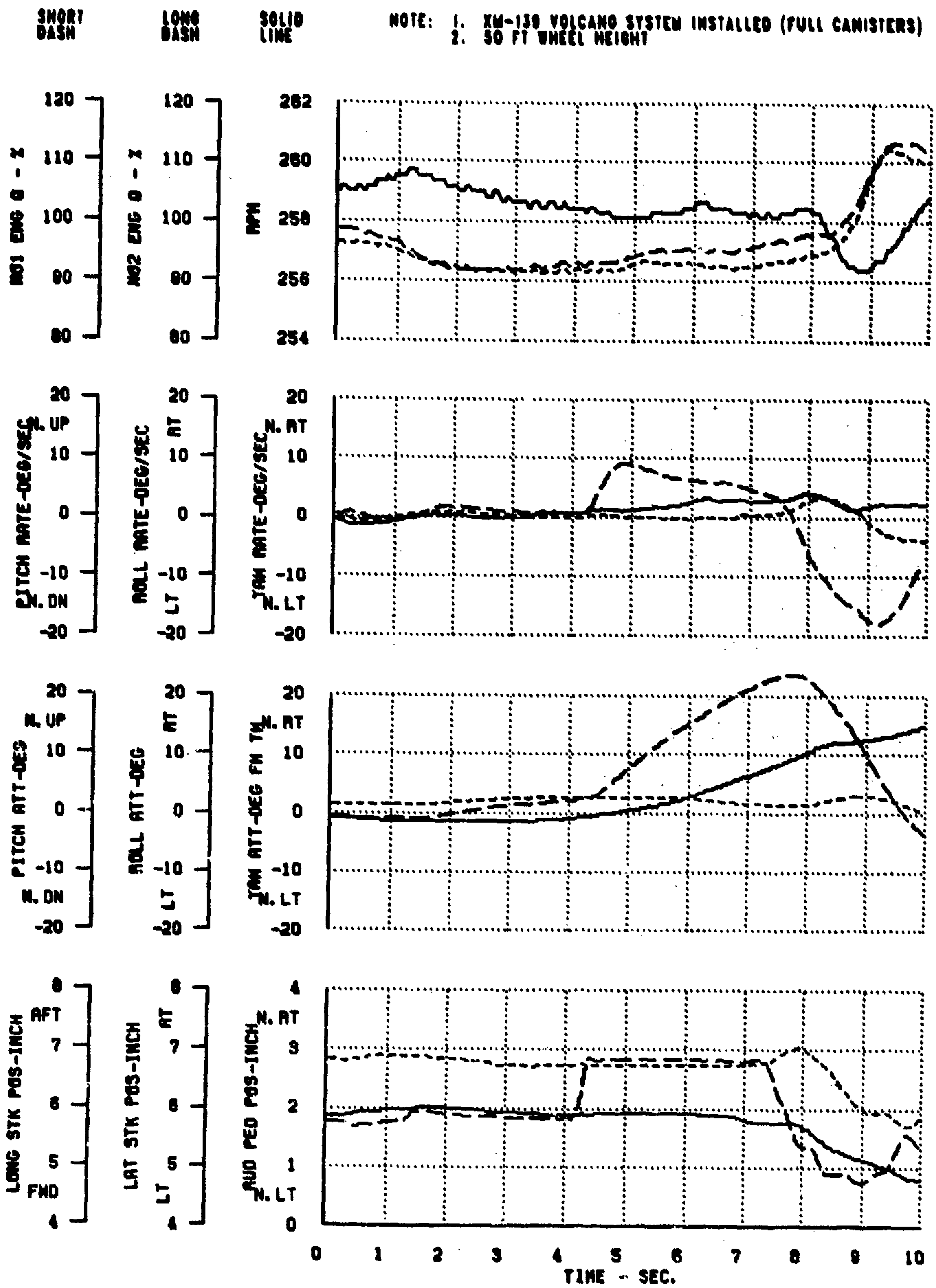


FIGURE 46

DIRECTIONAL CONTROLLABILITY

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20100	349.0MID	0.3 LT	-140	15.5	259	000

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

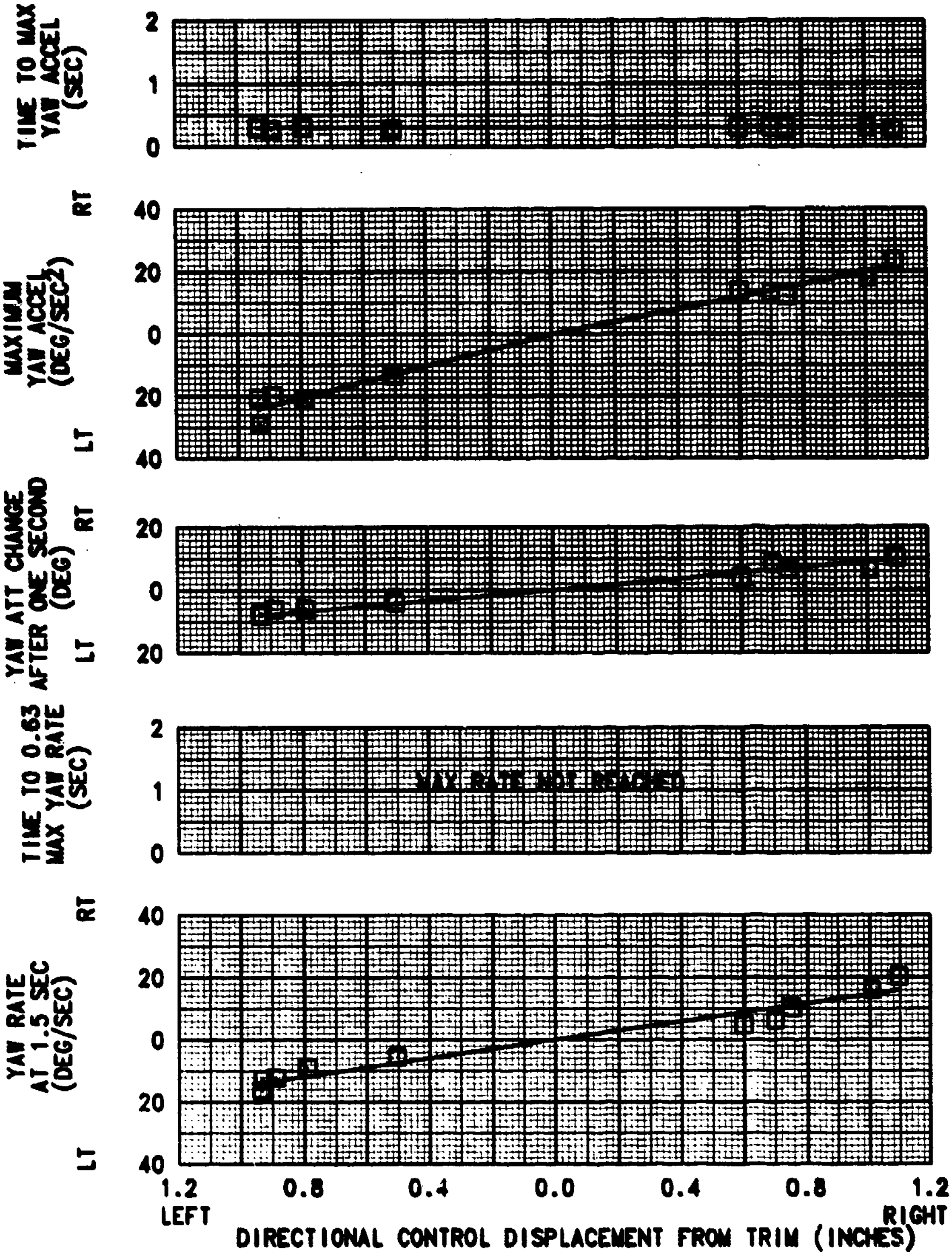


FIGURE 47
LEFT DIRECTIONAL STEP
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20200	349.6 MID	0.3 LT	-160	15.3	258	000

SHORT DASH LONG DASH SOLID LINE

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

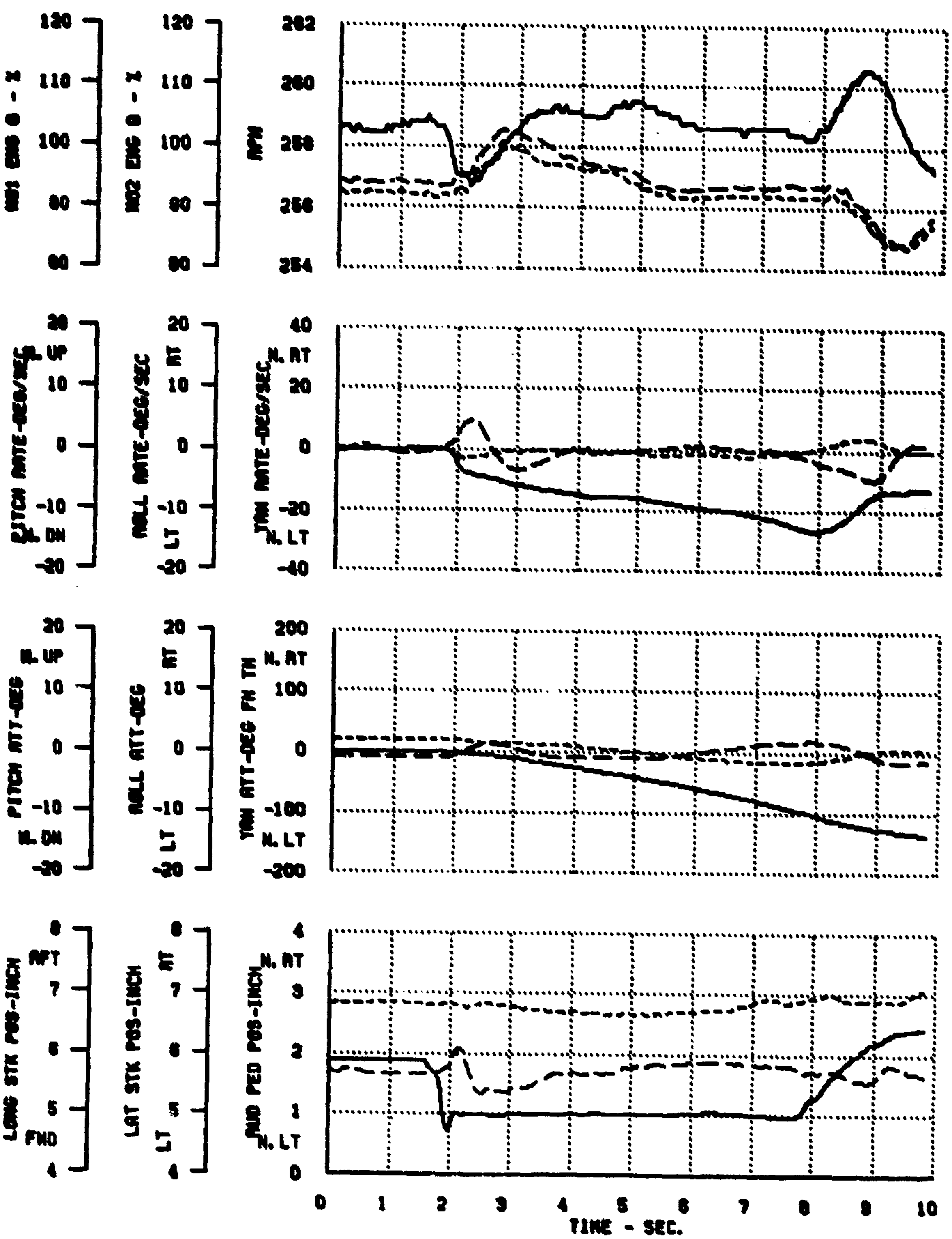


FIGURE 48

RIGHT DIRECTIONAL STEP

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)
20020	348.9 MID	0.3 LT	-140	15.6	25?	000

SHORT DASH LONG DASH SOLID LINE

NOTE: 1. XM-139 VOLCANO SYSTEM INSTALLED (FULL CANISTERS)
2. 50 FT WHEEL HEIGHT

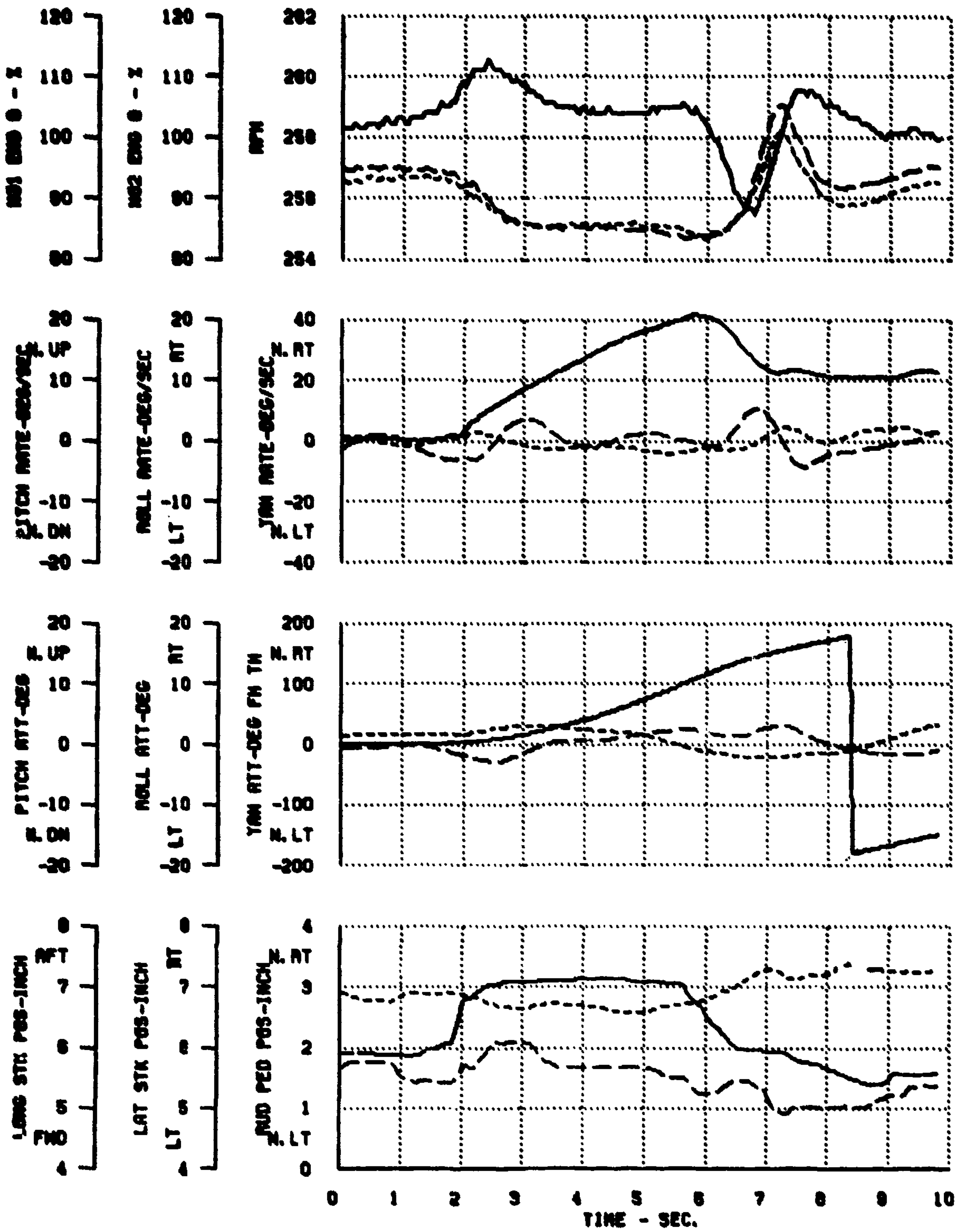


FIGURE 40
LOW SPEED FORWARD AND REARWARD FLIGHT CHARACTERISTICS
UH-60A USA S/N 84-23953

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG WHEEL HEIGHT (FT)	AIRCRAFT CONFIGURATION
☐	[illegible]	351.3MID	0.3 LT	630	21.5	258	30	VOLCANO
○	[illegible]	350.7MID	0.3 LT	-340	14.0	258	30	VOLCANO

NOTE: 1. VERTICAL LINES DENOTE CONTROL EXCURSIONS
2. FBA CENTERED AND LOCKED

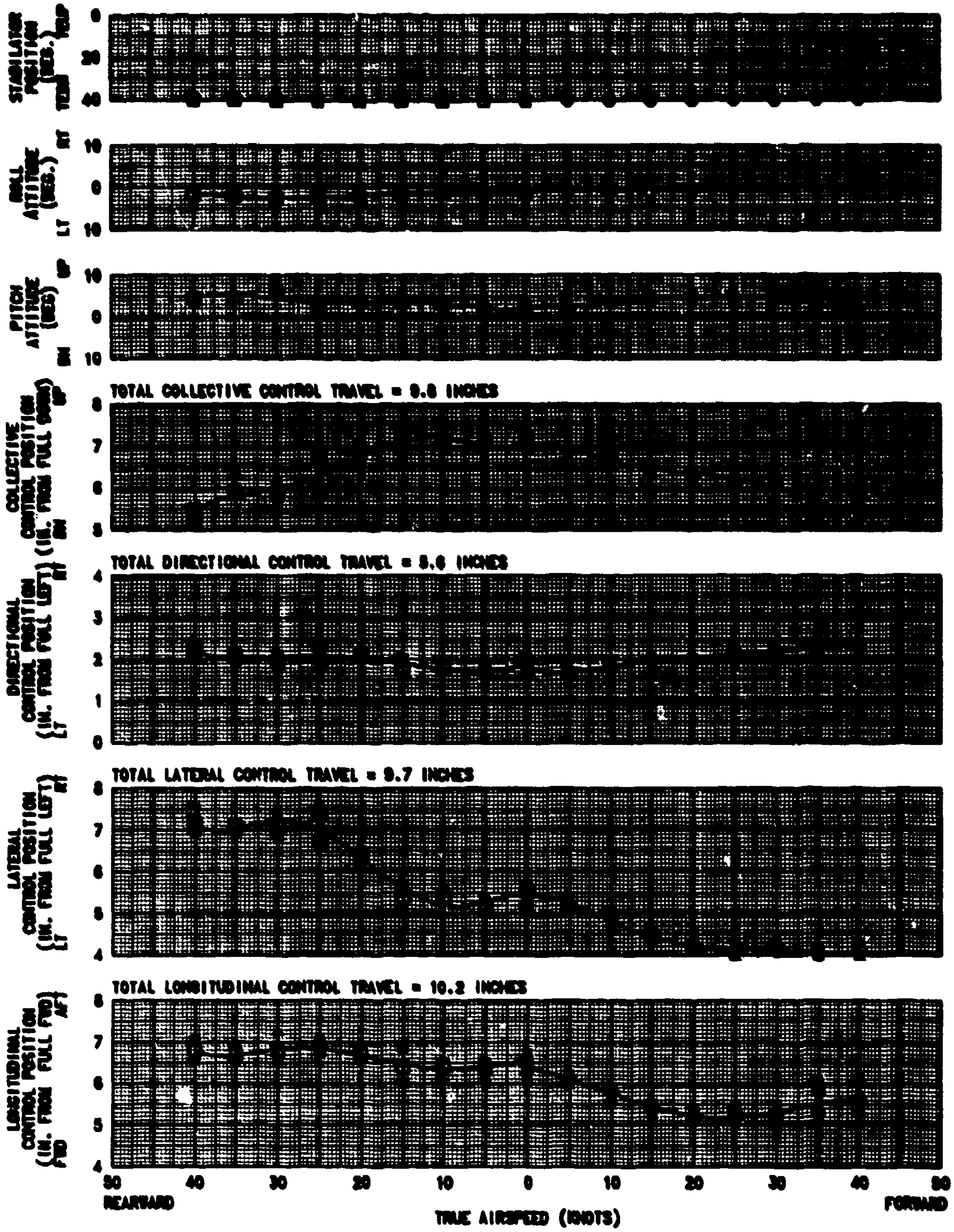


FIGURE 90

LOW SPEED RIGHT AND LEFT SIDEWARD FLIGHT CHARACTERISTICS

UH-60A USA S/N 84-23883

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG WHEEL HEIGHT (FT)	AIRCRAFT CONFIGURATION
□	20810	361.2MID	0.3 LT	480	19.5	258	30	VOLCANO
○	20570	360.3MID	0.25 LT	-30	15.3	258	30	VOLCANO

NOTE: 1. VERTICAL LINES DENOTE CONTROL EXCURSIONS
2. FBA CENTERED AND LOCKED

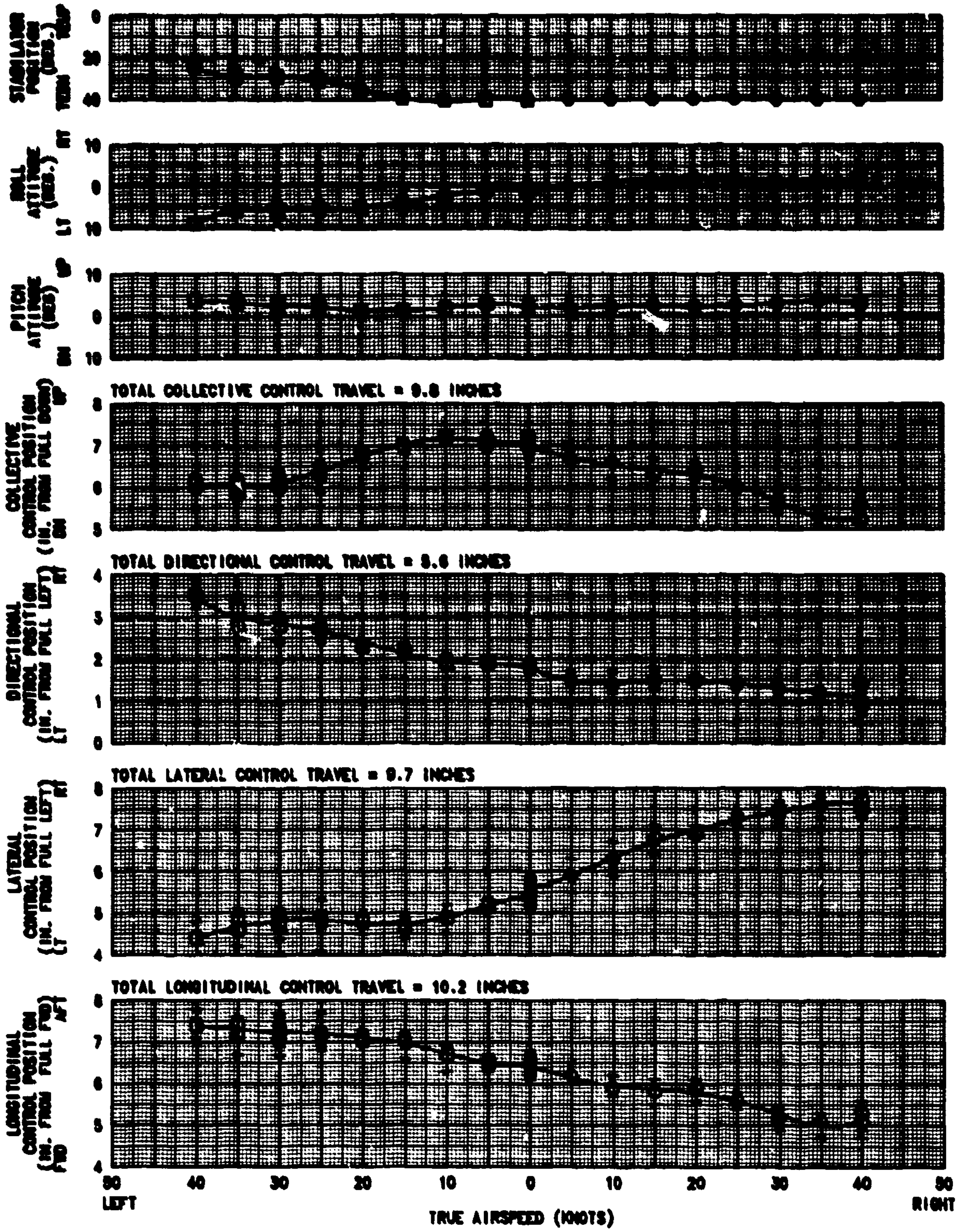


FIGURE 51
LOW SPEED 315 DEGREE AZIMUTH FLIGHT CHARACTERISTICS
UH-60A USA S/N 84-23983

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	AVG WHEEL HEIGHT (FT)	AIRCRAFT CONFIGURATION
20810	361.0MID	0.3 LT	630	21.5	258	30	VOLCANO

NOTE: 1. VERTICAL LINES DENOTE CONTROL EXCURSIONS
2. PBA CENTERED AND LOCKED

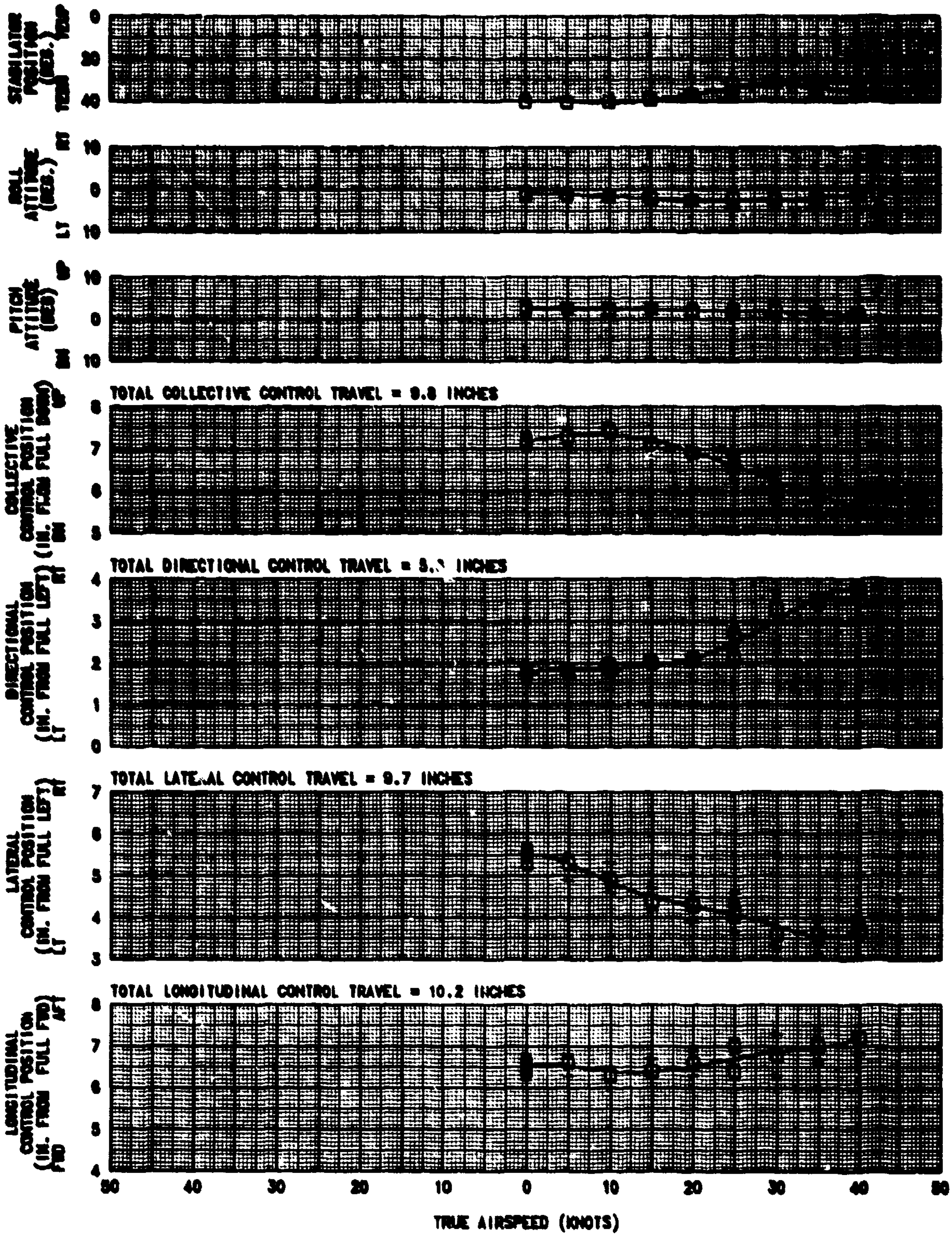


FIGURE 92
SIMULATED SINGLE ENGINE FAILURE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20380	350.3MID	0.3 LT	5100	14.0	258	82	ON	VOLCANO	LEVEL

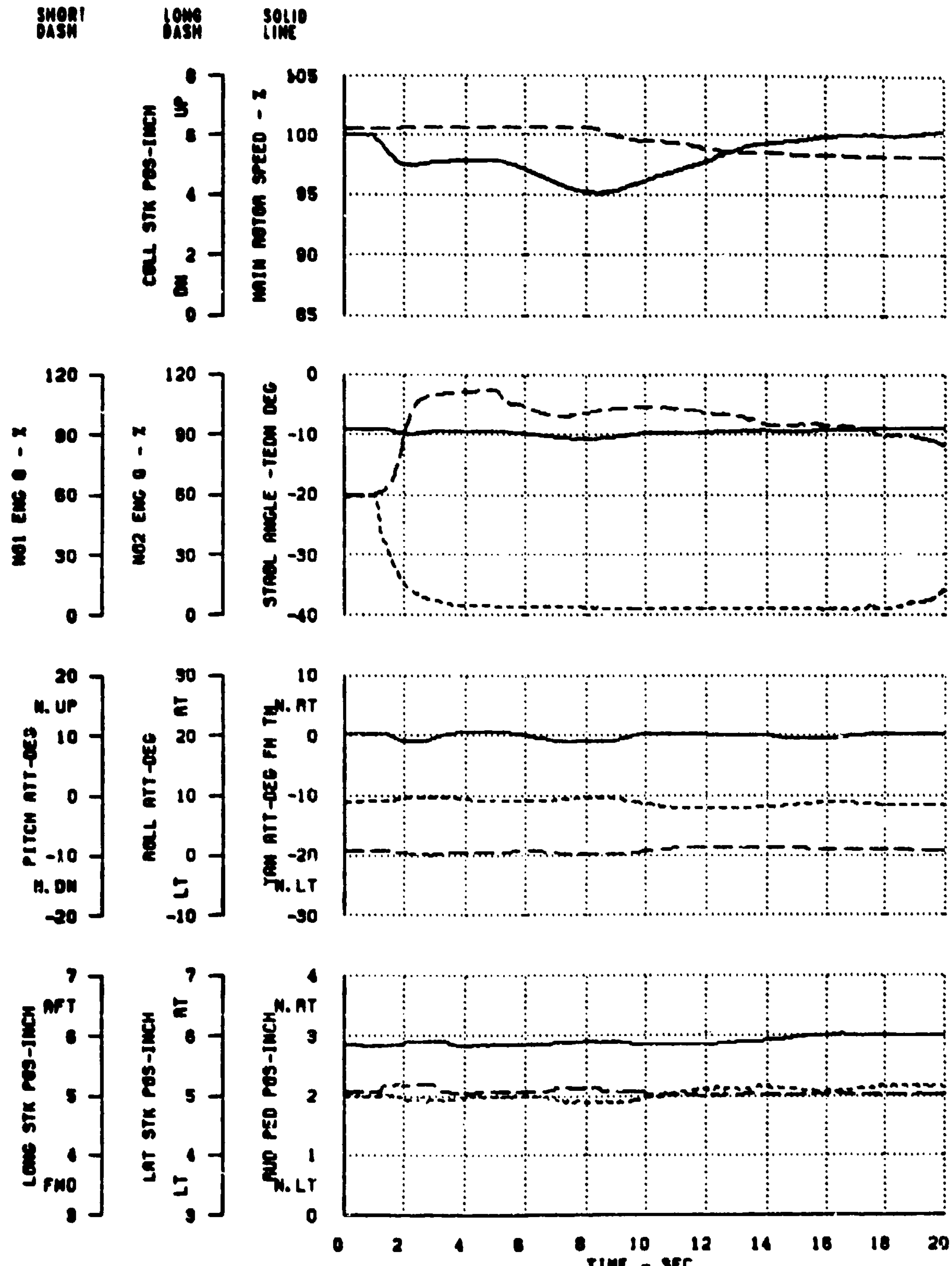


FIGURE 53
SIMULATED SINGLE ENGINE FAILURE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20220	349.7 MID	0.3 LT	5300	15.0	258	118	ON	VOLCANO	LEVEL

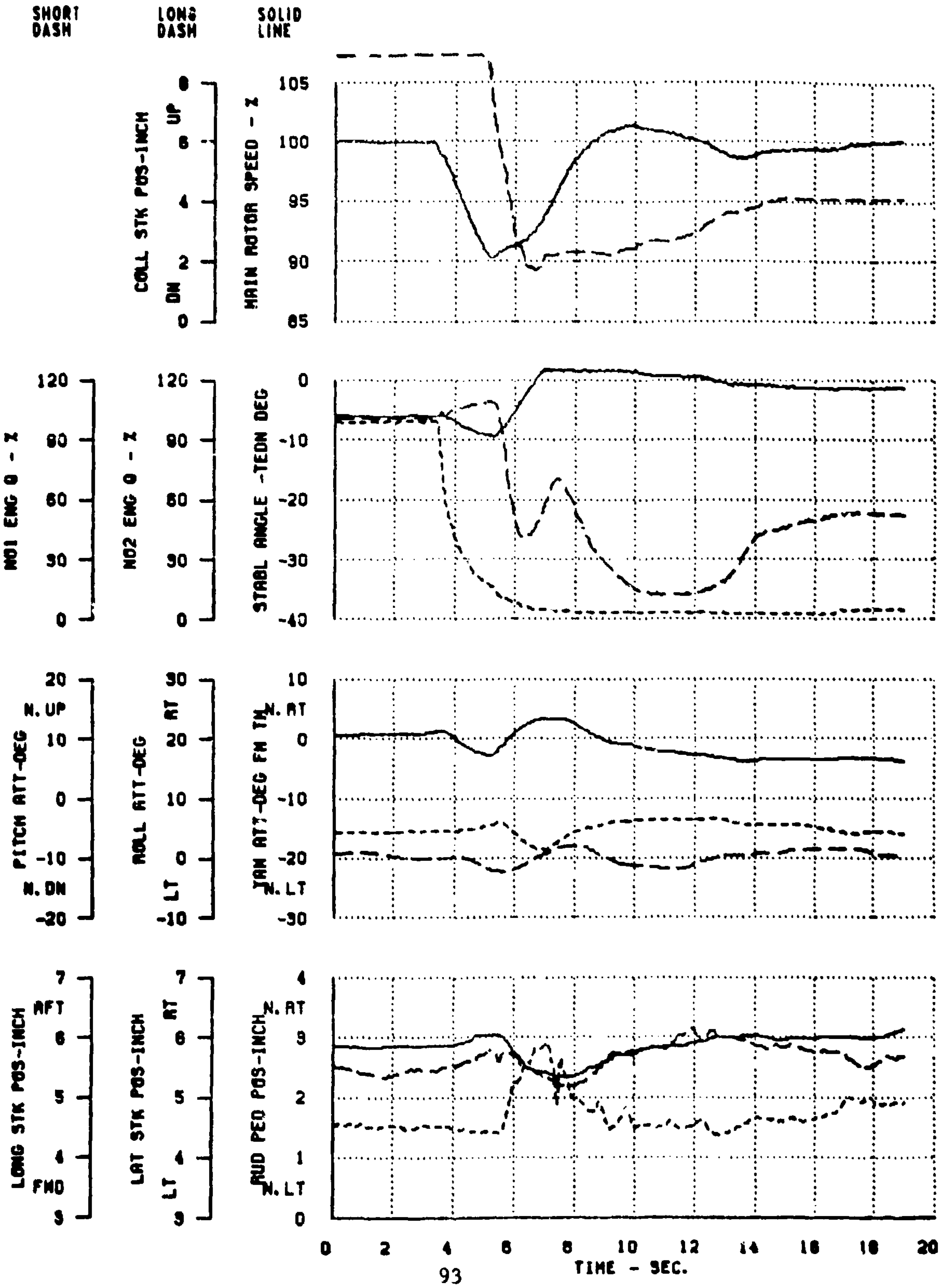


FIGURE 54
SIMULATED SINGLE ENGINE FAILURE
UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG CG LOCATION LONG (FS)	AVG CG LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FT)	AVG OAT (DEG C)	AVG ROTOR SPEED (RPM)	TRIM CALIBRATED AIRSPEED (KTS)	SAS CONDITION	AIRCRAFT CONFIGURATION	FLIGHT CONDITION
20100	349.8MID	0.3 LT	3260	14.9	258	85	ON	VOLCANO	IRP CLIMB

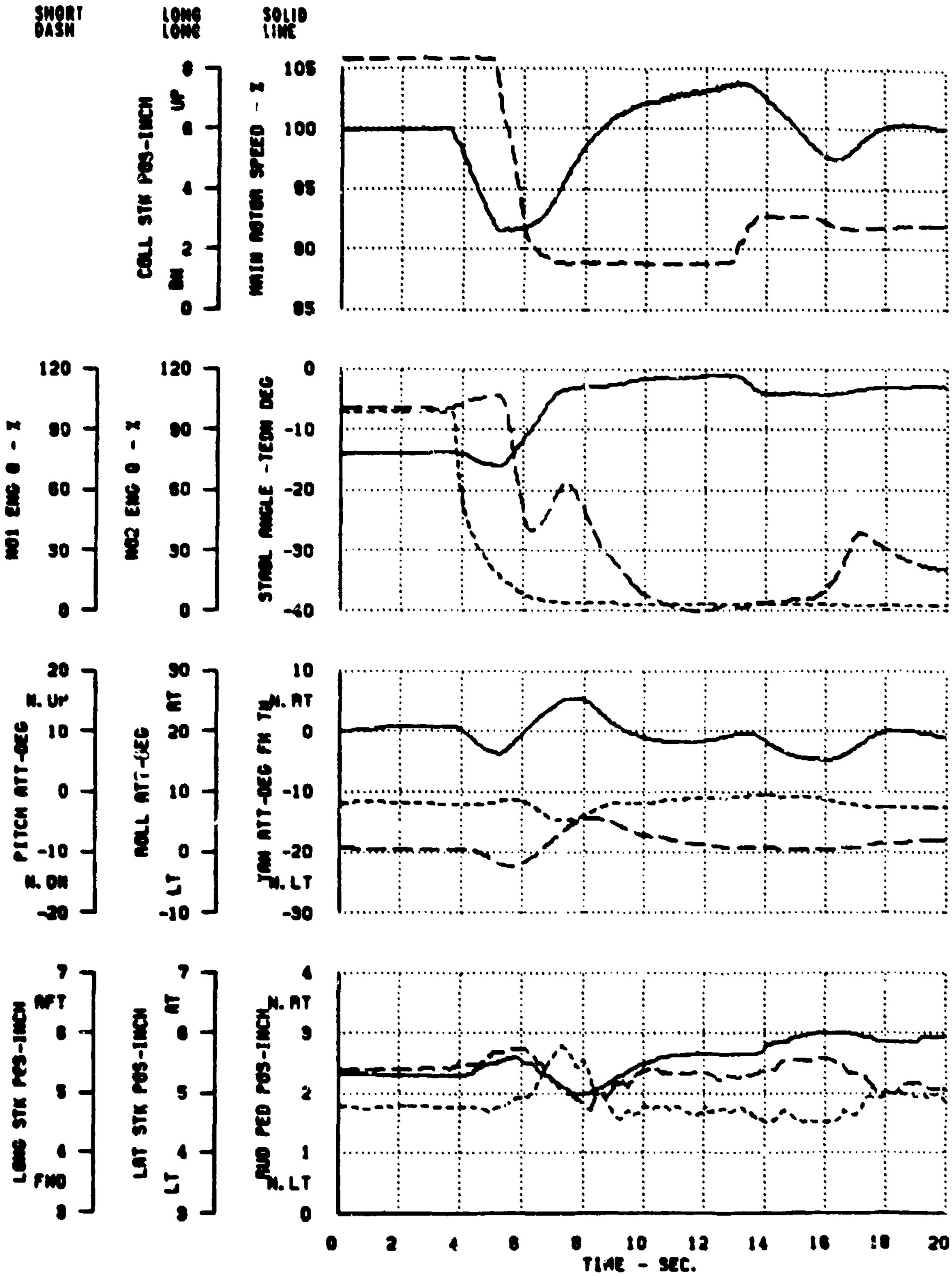


FIGURE 55
SHIP AIRSPEED CALIBRATION
UH-60A USA S/N 84-23953

SYM	AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
⊙	15270	350.6	0.2	3350	13.5	TRAILING BOMB
Δ	18600	350.6	0.2	6200	17.5	TRAILING BOMB
⊡	17500	350.0	0.2	-10	16.0	GRND SPD CRSE

NOTES: 1. NORMAL UTILITY CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM

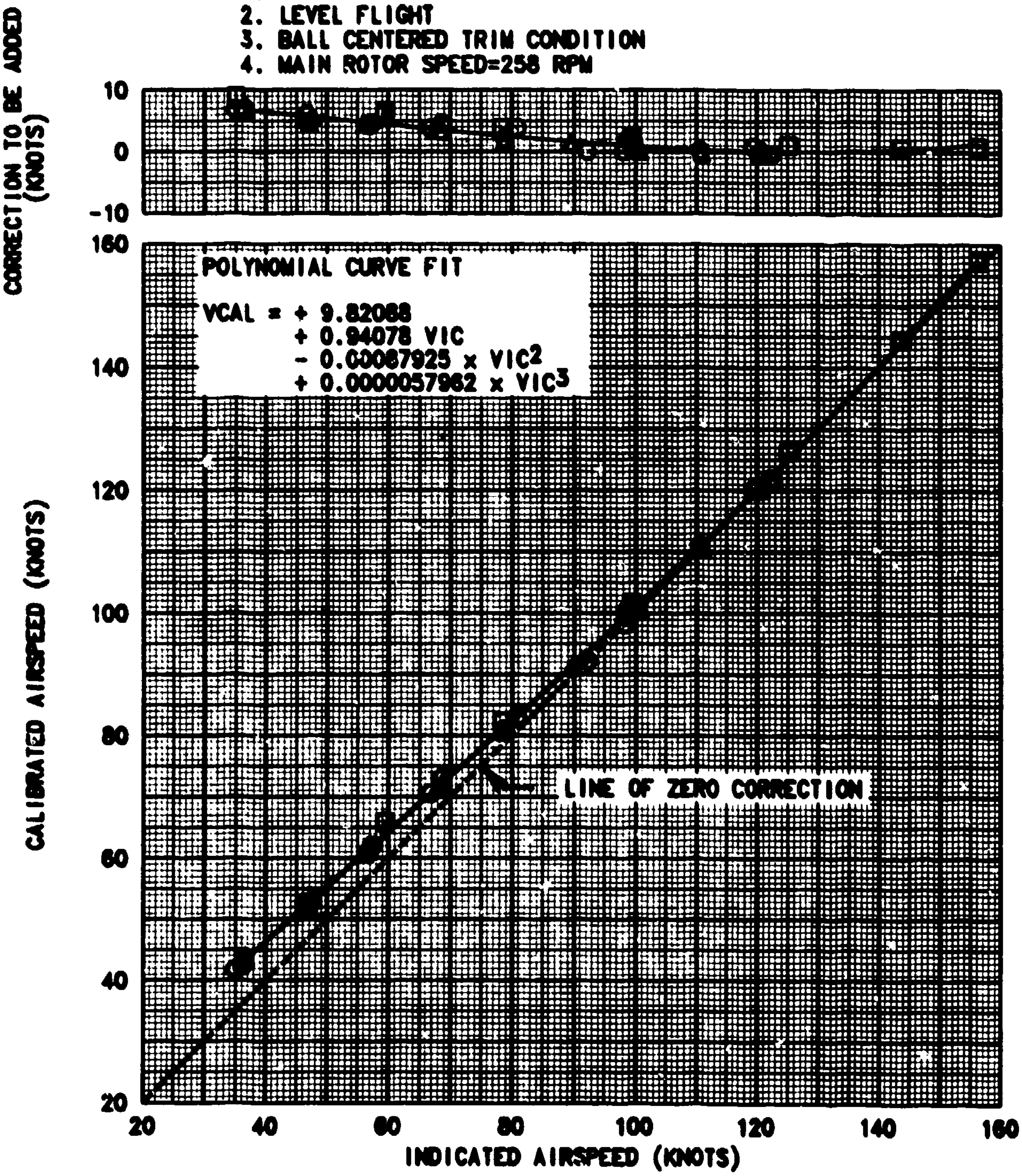


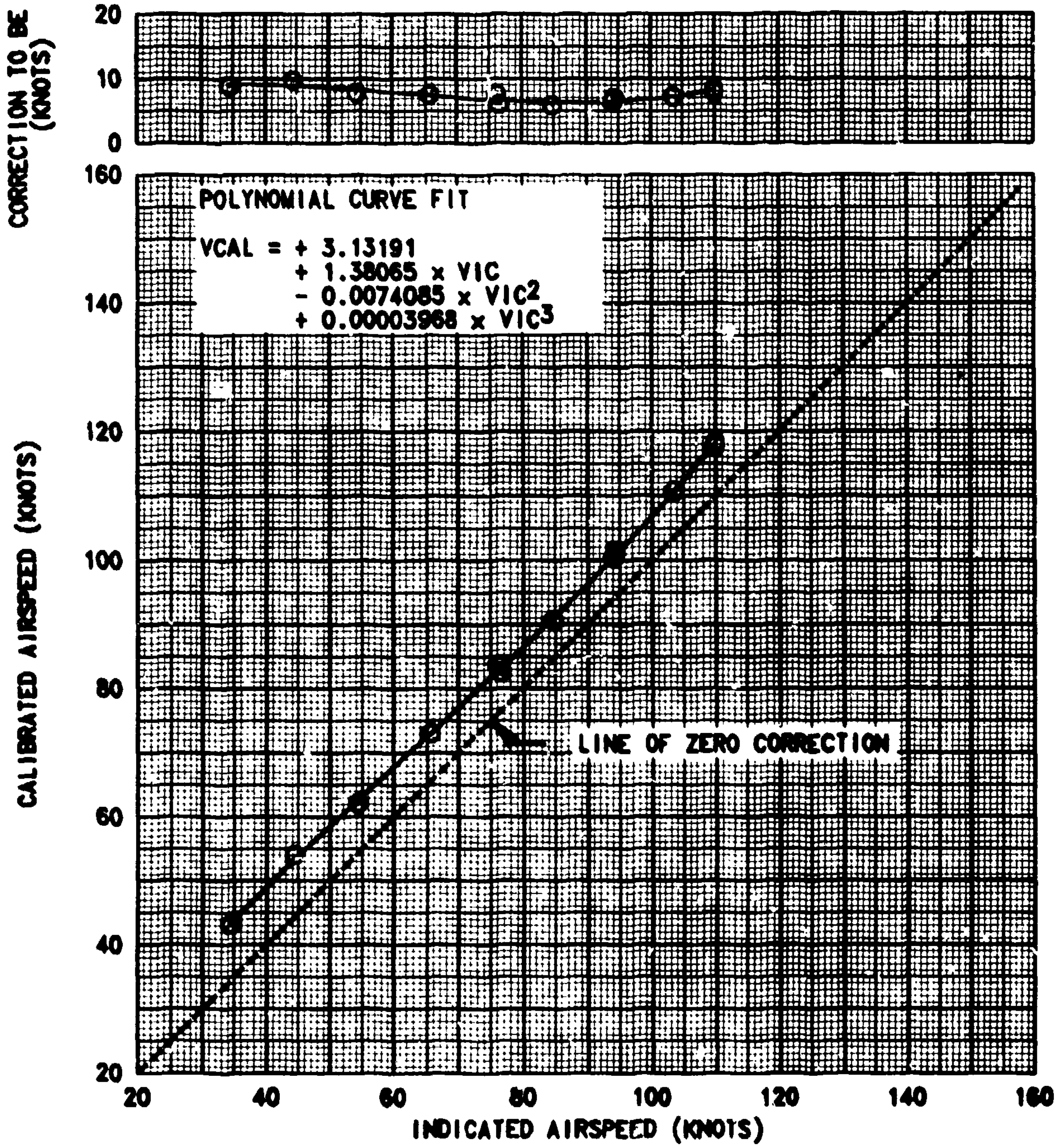
FIGURE 58

SHIP AIRSPEED CALIBRATION

UH-60A USA S/N 84-23953

AVG GROSS WEIGHT (LB)	AVG C.G. LOCATION LONG (FS)	AVG C.G. LOCATION LAT (BL)	AVG DENSITY ALTITUDE (FEET)	AVG OUTSIDE AIR TEMP. (DEG C)	TEST METHOD
20570	350.8	0.2	5200	6.5	TRAILING BOMB

NOTES: 1. VOLCANO CONFIGURATION
2. LEVEL FLIGHT
3. BALL CENTERED TRIM CONDITION
4. MAIN ROTOR SPEED=258 RPM



APPENDIX F. PHOTOGRAPHS

Photograph	Photograph Number
Test Aircraft	1 through 4
VOLCANO Mounting Hardware	5 through 7
Fixed Provision Mounting Points	8 and 9
VOLCANO Launcher Racks	10 and 11
Launcher Racks with Canisters	12 and 13
Test Aircraft with VOLCANO Installed	14 and 15
Interface Control Panel	16
Ballast Locations	17 through 19
Instrumentation Package	20 and 21
External Modifications	22 through 25

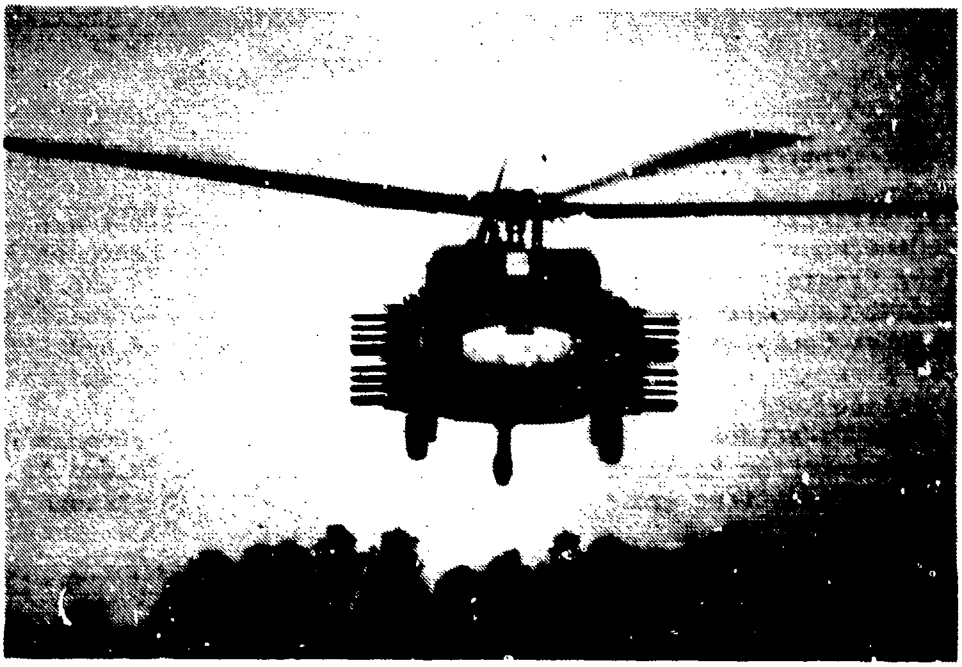


Photo 1. Front View, UH-60A Helicopter with XM-139 VOLCANO System Installed

Photo 2. Rear View, UH-60A Helicopter with XM-139 VOLCANO System Installed

Photo 3. Right Quarter View, UH-60A Helicopter
with XM-139 VOLCANO System Installed

Photo 4. Left Side View, UH-60A Helicopter
with XM-139 VOLCANO System Installed

Photo 5. Side View, VOLCANO Side Panel Installed

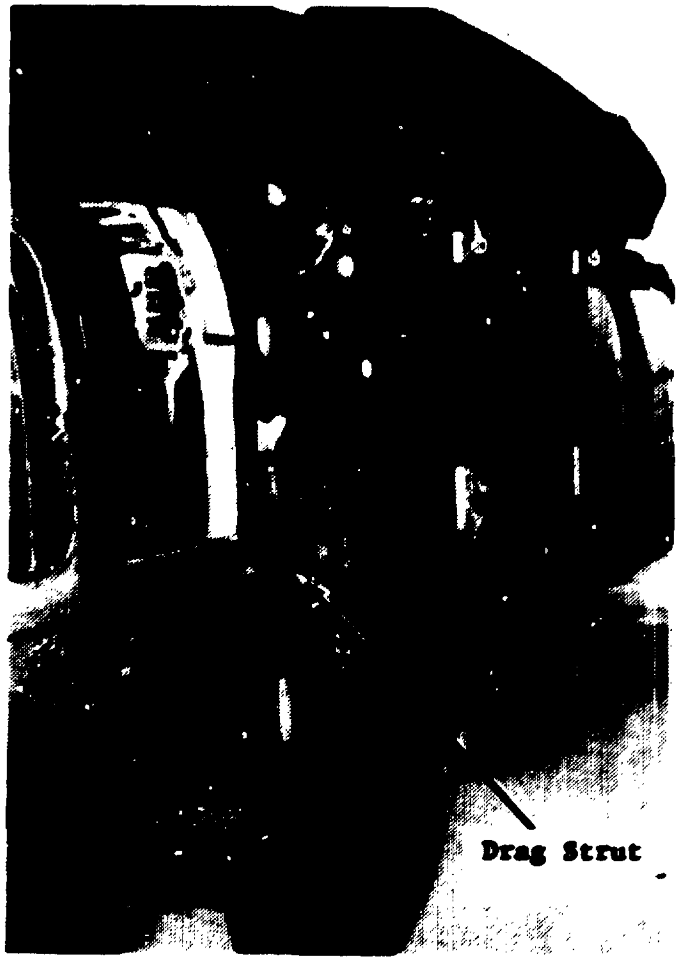


Photo 6. VOLCANO Side Panel Installed on Fixed Provision Mounting Points (Drag Strut in Stowed Position)

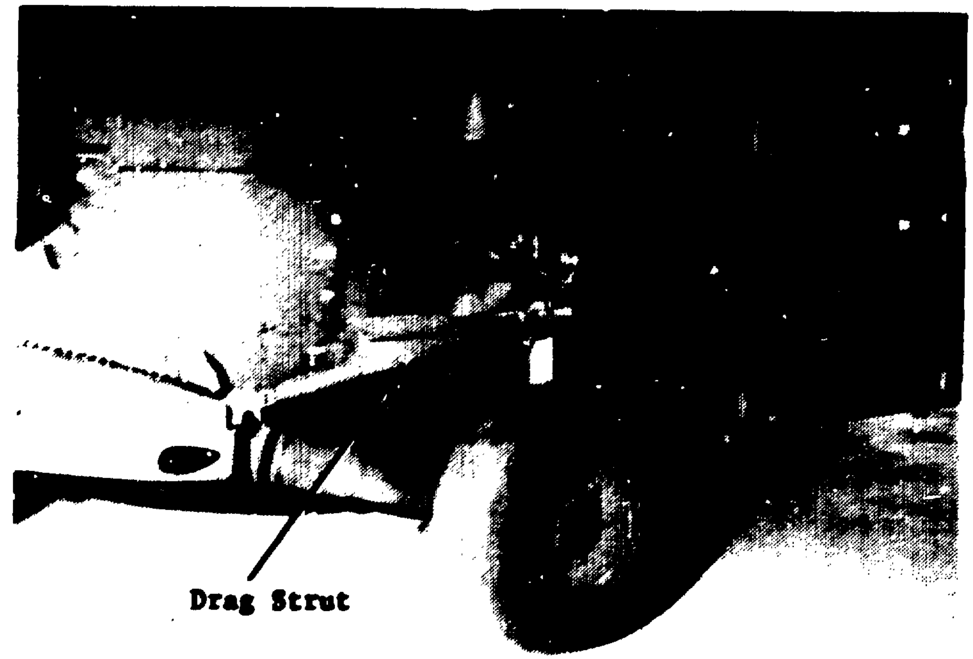


Photo 7. VOLCANO Side Panel Drag Strut Mounted to Stub Wing Fitting

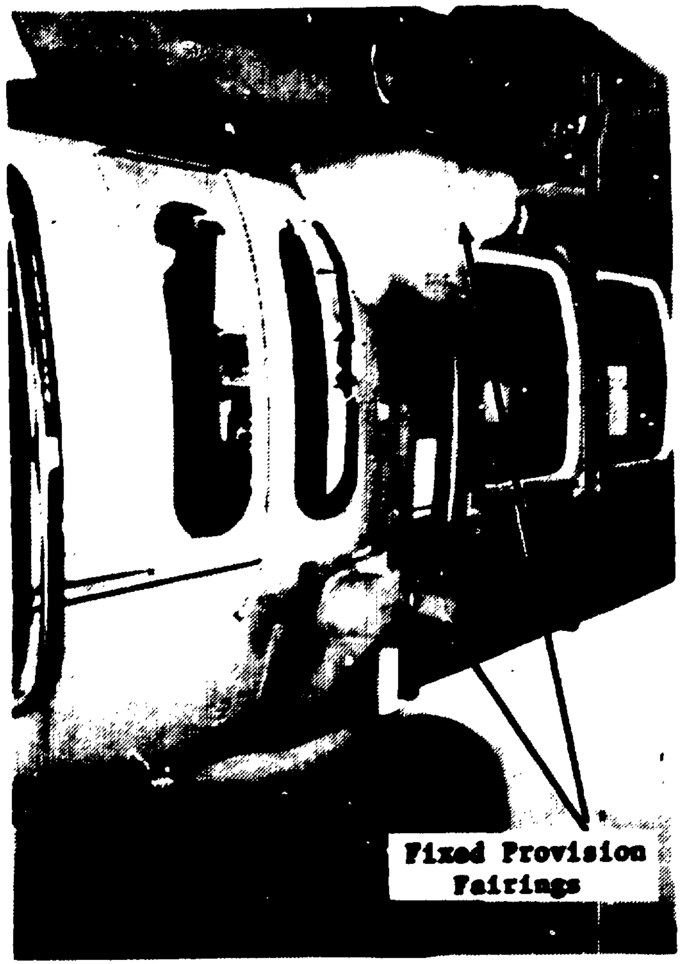


Photo 8. Fixed Provision Fairings Installed

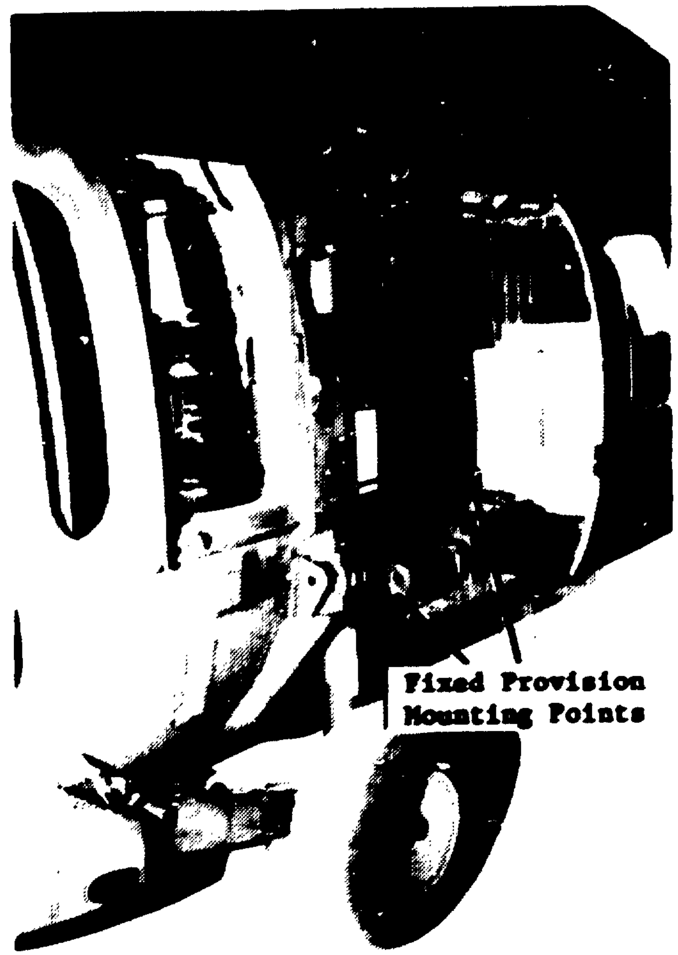


Photo 9. Fixed Provision Mounting Points with Fairings Removed

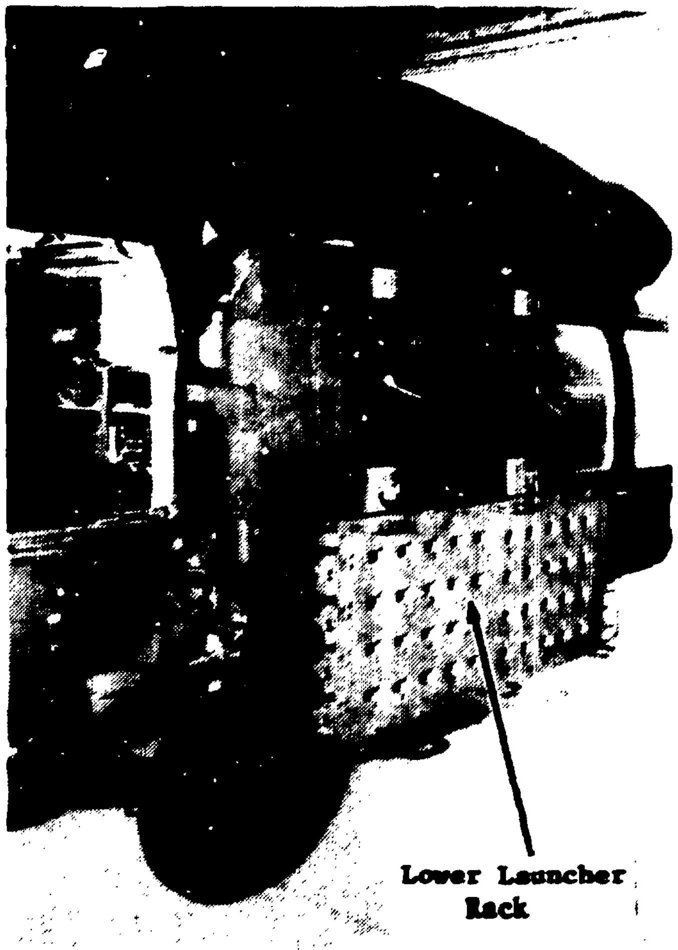


Photo 10. VOLCANO Lower Launcher Rack Installed on Side Panel

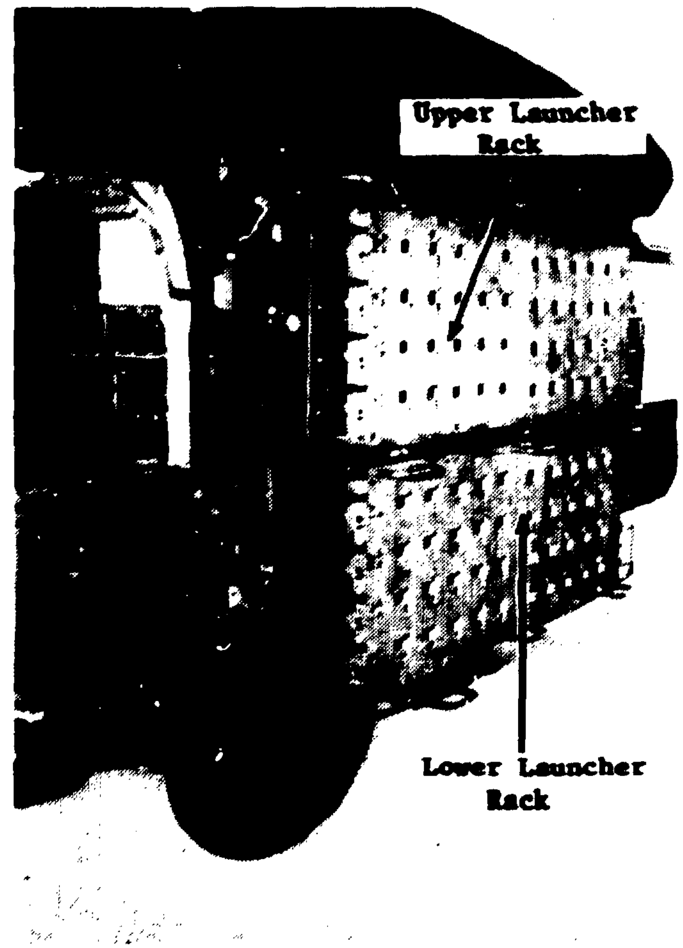


Photo 11. VOLCANO Upper and Lower Launcher Racks Installed on Side Panel

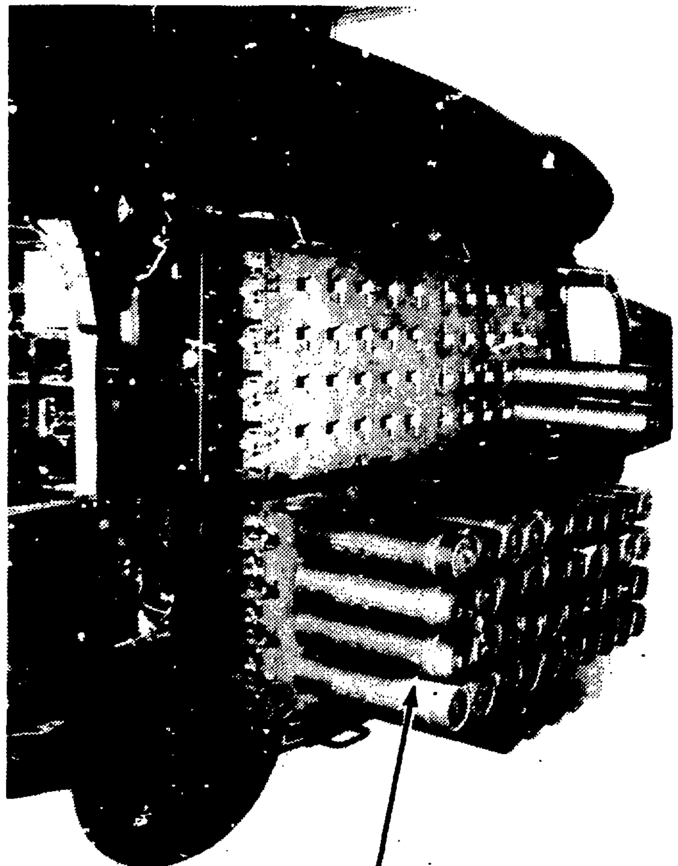


Photo 12. VOLCANO Launcher Racks During Installation of XM-88 (Practice) Mine Canisters

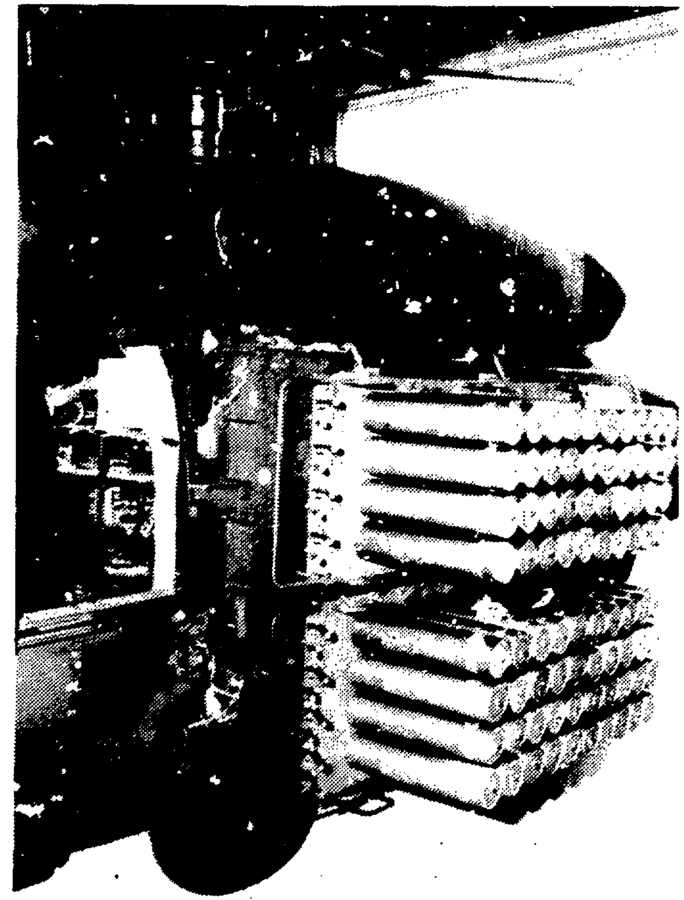


Photo 13. VOLCANO Launcher Racks Filled with XM-88 (Practice) Mine Canisters

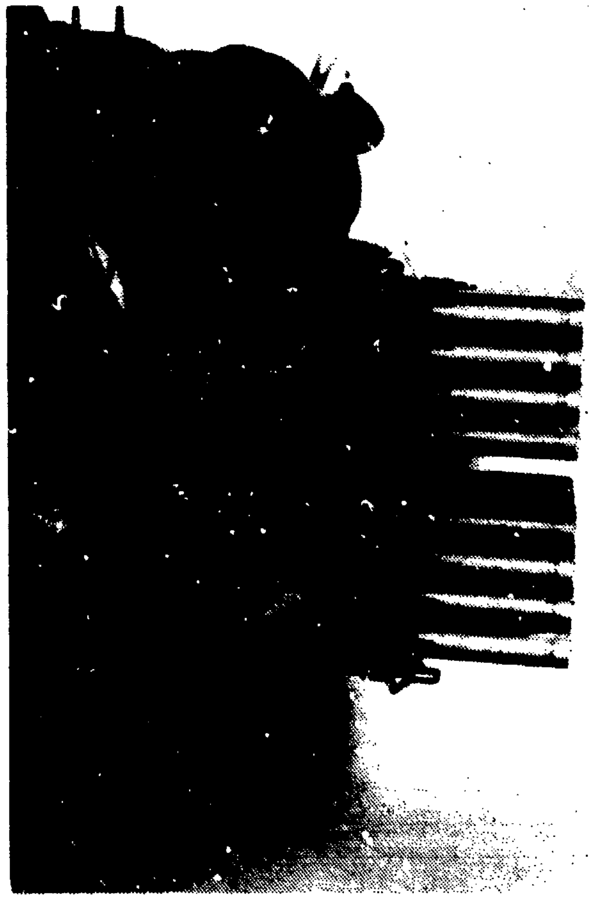


Photo 14. Front View, VOLCANO Side Panel, Launcher Racks, and XM-88 (Practice) Mine Canisters Installed

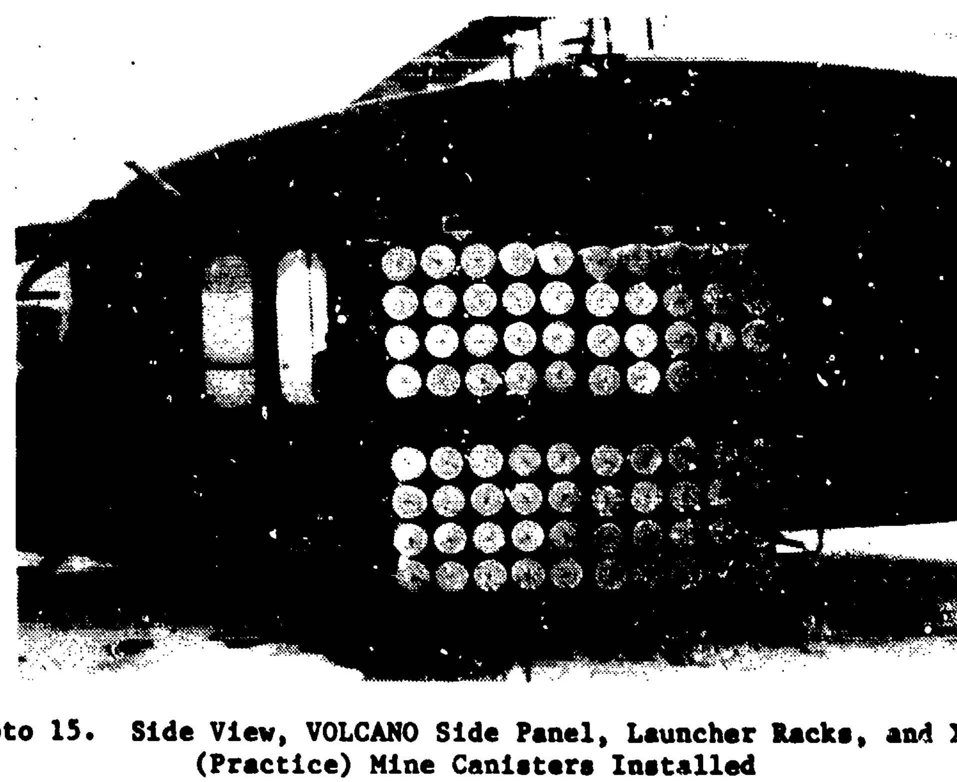


Photo 15. Side View, VOLCANO Side Panel, Launcher Racks, and XM-88 (Practice) Mine Canisters Installed

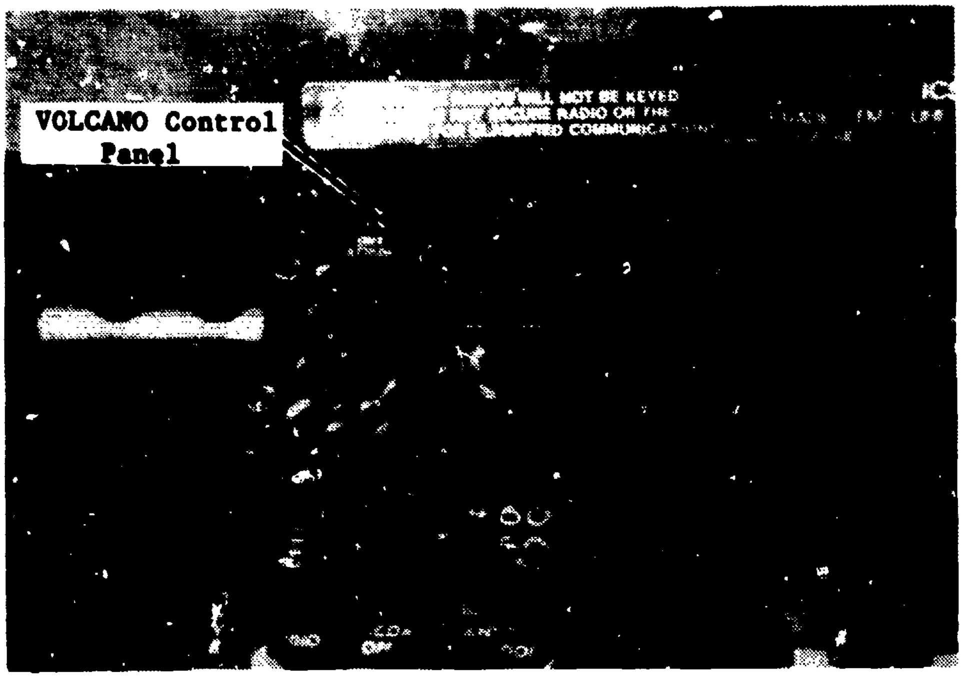


Photo 16. VOLCANO Interface Control Panel Installed in Cockpit Center Console (Forward Left Corner Location)

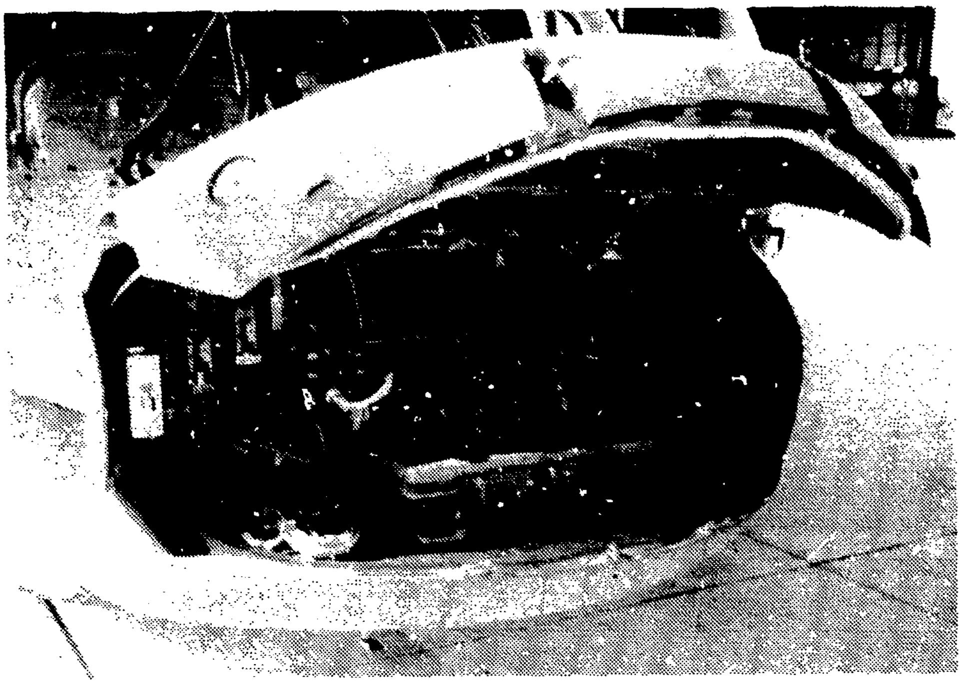


Photo 17. Nose-Bay Ballast Mounting Location

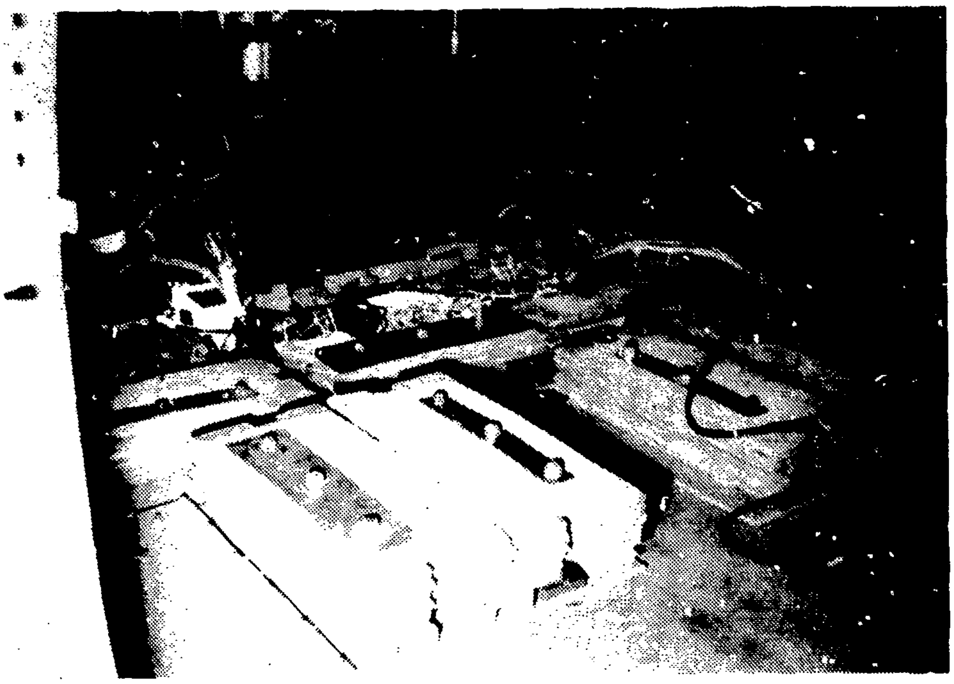


Photo 18. Floor Mounted Ballast Location Aft of Pilot Seats

Photo 19. Ballast Mounting Provisions Atop Fuel Cell and Forward of Bulkhead

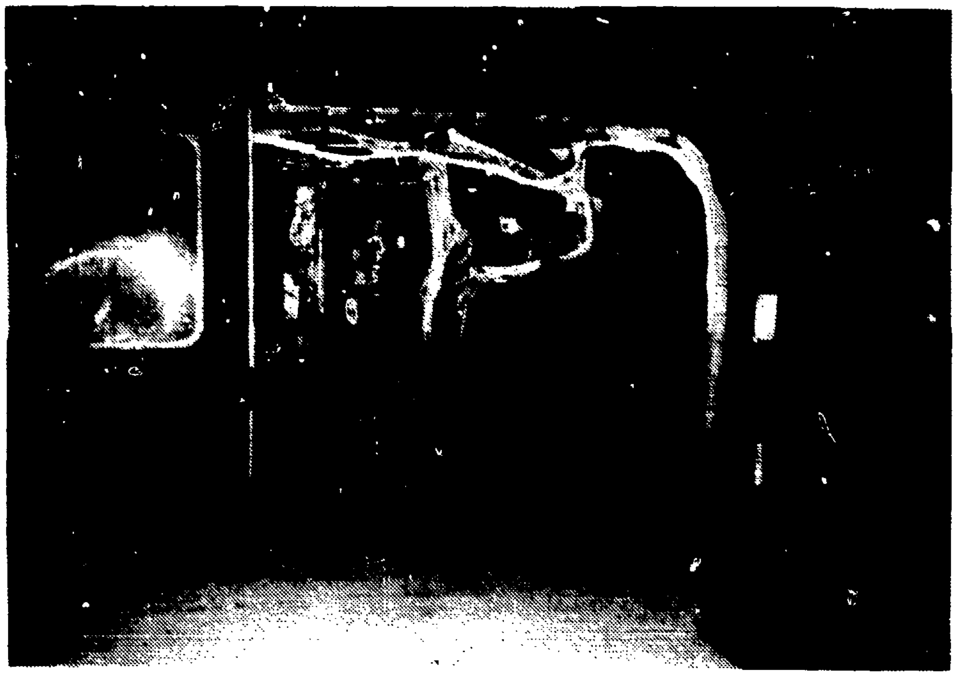


Photo 20. Right View of Test Instrumentation Installation

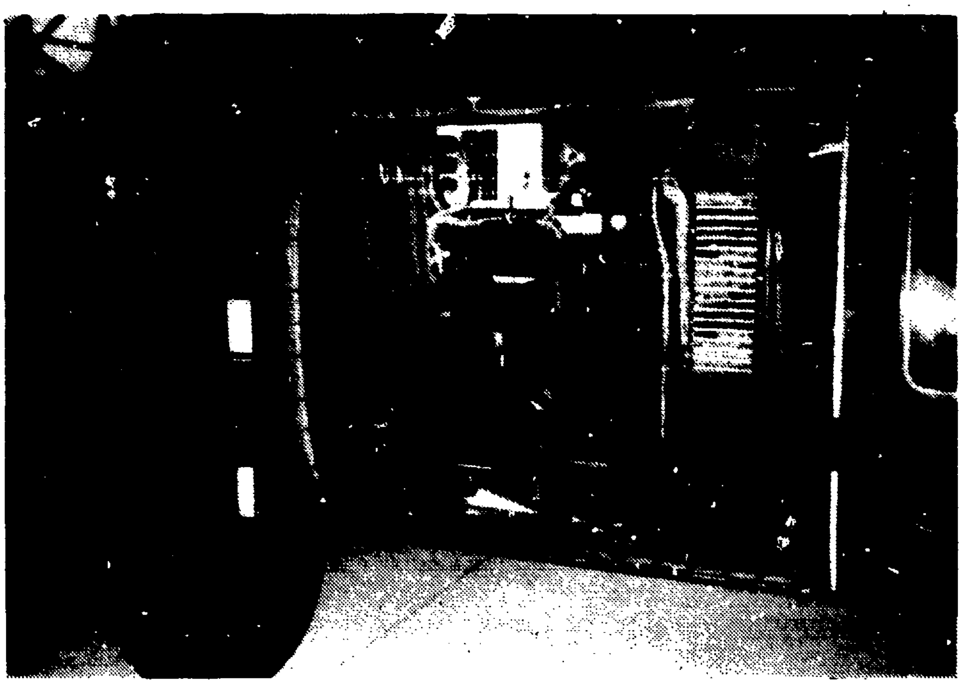


Photo 21. Left View of Test Instrumentation Installation

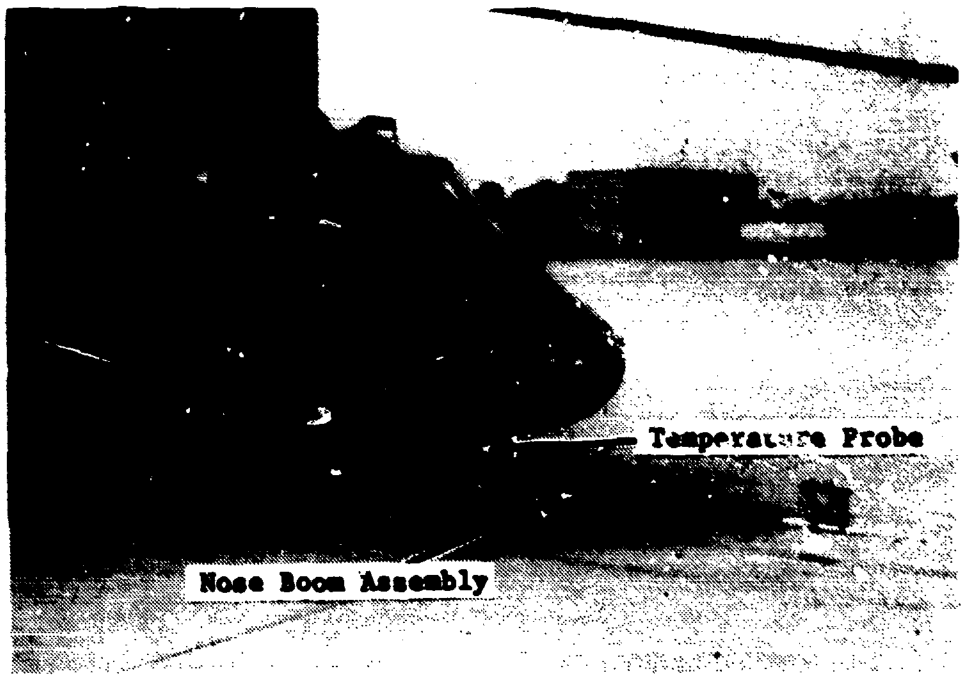


Photo 22. Boom System Installation and Nose-Mounted Temperature Probe

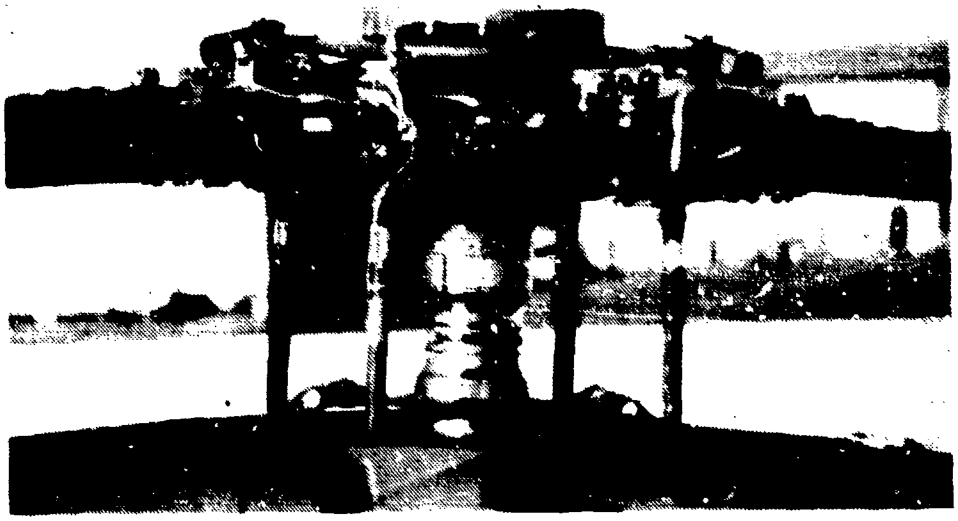


Photo 23. Main Rotor Instrumentation and Slip Ring Installation

Photo 24. Tail Rotor Instrumentation and Slip Ring Installation

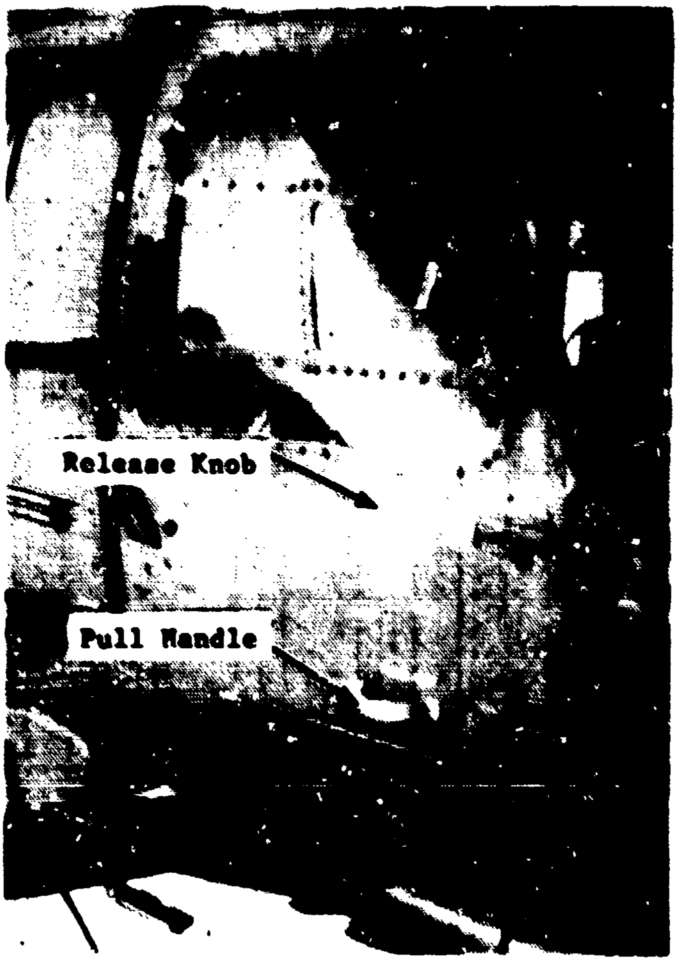


Photo 25. Emergency Crew Door Handles

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